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Doctoral Thesis

Rural Organisational Impacts, Responses, and Recoveries to Natural Disasters: Case studies from the Canterbury Earthquake Sequence and the 2010 Southland Snowstorm

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“First pants, then your shoes.”

-Gary Larson

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Abstract

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Rural Organisational Impacts, Responses, and Recoveries to Natural Disasters: Case studies from the Canterbury Earthquake Sequence and the 2010 Southland Snowstorm

by Zach Whitman

Natural disasters are increasingly disruptive events that affect livelihoods, organisations, and economies worldwide. Research has identified the impacts and responses of organisations to different types of natural disasters, and have outlined factors, such as industry sector, that are important to organisational vulnerability and resilience. One of the most costly types of natural disasters in recent years has been earthquakes, and yet to date, the majority of studies have focussed on the effects of earthquakes in urban areas, while rural organisational impact studies have primarily focused on the effects of meteorological and climatic driven hazards. As a result, the likely impacts of an earthquake on rural organisations in a developed context is unconstrained in the literature. In countries like New Zealand, which have major earthquakes and agricultural sectors that are significant contributors to the economy, it is important to know what impacts an earthquake event would have on the rural industries, and how these impacts compare to that of a more commonly analysed, high-frequency event.

In September of 2010, rural organisations in Canterbury experienced the 4 September 2010 M_w 7.1 'Darfield' earthquake and the associated aftershocks, which came to be known as the Canterbury earthquake sequence. The earthquake sequence caused intense ground shaking, creating widespread critical service outages, structural and non-structural damage to built infrastructure, as well as ground surface damage from flooding, liquefaction and surface rupture. Concurrently on September 18 2010, rural organisations in Southland experienced an unseasonably late snowstorm and cold weather snap that brought prolonged sub-zero temperatures, high winds and freezing rain, damaging structures in the City of Invercargill and causing widespread livestock losses and production decreases across the region.

This thesis documents the effects of the Canterbury earthquake sequence and Southland snowstorm on farming and rural non-farming organisations, utilizing comparable methodologies to analyse rural organisational impacts, responses and recovery strategies to natural disasters. From the results, a short-term impact assessment methodology is developed for multiple disasters. Additionally, a regional asset repair cost estimation model is proposed for farming organisations following a major earthquake event, and the use of social capital in rural organisational recovery strategies following natural disasters is analysed.

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Contents

List of Figures

List of Tables

Abbreviations

ANZSIC	**A**ustralian and **N**ew **Z**ealand **S**tandard **I**ndustrial **C**lassification
ARC	**A**sset **R**epair **C**osts
BI	**B**usiness **I**nterruption
BRT	**B**enchmark **R**esilience **T**ool
CBD	**C**entral **B**usiness **D**istrict
CDEM	**C**ivil **D**efence and **E**mergency **M**anagement
CHCH	**CH**rist**CH**urch
CREDS	**C**anterbury **R**egional **E**conomic **D**evelopment **S**trategy
ECAN	**E**nvironment **CAN**terbury
EQC	**E**arth**Q**uake **C**ommission
ESS	**E**arthquake **S**upport **S**ubsidy
ETFG	**E**nhanced **T**ask **F**orce **G**reen
FEMA	**F**ederal **E**mergency **M**anagement **A**gency (US)
FMCG	**F**ast **M**oving **C**onsumer **G**oods
FTE	**F**ull-**T**ime **E**quivalent
HEC	**H**uman **E**thics **C**ommittee
ICT	**I**nformation **C**ommunication **T**echnology
IT	**I**nformation **T**echnology
MAF	**M**inistry of **A**griculture and **F**orestry
MCDEM	**M**inistry of **C**ivil **D**efense and **E**mergency **M**anagement
MMI	**M**odified **M**ercalli **I**ntensity scale
MPI	**M**inistry of **P**rimary **I**ndustries
NHRP	**N**atural **H**azard **R**esearch **P**latform
NIWA	**N**ational **I**nstitute **W**ater and **A**tmospheric Research
NGO	**N**on-**G**overnmental **O**rganisation

NZD	**N**ew **Z**ealand **D**ollar
OECD	**O**rganisation for **E**conomic **C**o-operation and **D**evelopment
OII	**O**rganisational **I**mpact **I**ndex
PGA	**P**eak **G**round **A**cceleration
RAP	**R**ural **A**ssistance **P**ayments
RIF	**R**elative **I**mpact **F**actor
RQ	**R**esilience **Q**uestionnaire
RRG	**R**ural **R**ecovery **G**roup
RST	**R**ural **S**upport **T**rust
SME	**S**mall and **M**edium **E**nterprises
SRM	**S**pecial **R**ecovery **M**easure
TARC	**T**otal **A**sset **R**epair **C**osts
TFG	**T**ask **F**orce **G**reen
UK	**U**nited **K**ingdom
URM	**U**n**R**einforced **M**asonry
USD	**U**nited **S**tates **D**ollar
VCSN	**V**irtual **C**limate **S**tation **N**etwork

Chapter 1

Natural disasters and rural organisations in New Zealand

Natural disasters are increasingly costly events that threaten life, infrastructure, and economies. Over the last 60 years, recorded economic and insured losses resulting from natural disasters such as earthquakes have risen steadily despite the number of events remaining relatively static [1]. This increase in costliness has prompted governments, NGOs and academics to document and analyse the impacts of earthquakes – and natural disasters in general – in an effort to understand how impacts can be reduced. As a result, much of the work over the last 30 years has helped explain how natural disasters impact individuals, organisations, communities, states or countries. The work has also provided the empirical evidence necessary to forecast the likely impacts of a variety of natural disaster scenarios, although this has typically been limited to developed countries.

Because the economic and social cost of events is of growing concern, the number of organisational impact studies following natural disasters is also increasing in the disaster literature (e.g. [2–8]). These studies have collected a wide variety of data from a number of different analytical frames, including the sources of disruption for some types of organisations, the repair costs following different events, and the factors helpful in mitigating the effects of the disaster. However, the majority of these studies have focussed on businesses or industries in urban areas. One context that has been largely overlooked to date has been the rural areas or the primary sectors within the context of a highly developed country. Only recently has it been argued that there is an impending need for further impact data collection initiatives for agricultural organisations [9].

From agricultural studies, rural sociology studies, and economic analyses, it is evident that natural disasters can complexly impact primary producers and create significant flow-on effects for non-farm rural organisations [10, 11], local communities [12–14], and the global marketplace [15]. These studies generally focus on high-frequency events, such as storms or droughts, and consequently the impacts of these events to farming organisations and the surrounding communities are well documented (e.g. [16–22]). The impact of low-frequency events, specifically earthquakes, are notably absent in the literature and consequently very little is known about how a major earthquake event would affect rural organisations, or how these impacts would compare to a more common hazard like a storm.

The purpose of this chapter is to present the evolution of the idea of natural disasters and the conceptual frameworks of vulnerability, resilience, and disaster risk reduction. These conceptual frameworks are presented as they relate to the problem of mitigating the impacts of natural hazards on social systems. This chapter then addresses the context-specific nature of the industries of rural New Zealand, and how these industries are vulnerable and resilient to natural hazards. Finally, the overall structure of this thesis is presented.

1.1 The 'natural' in natural disasters

For those affected, natural disasters are often viewed as an adversary, an aberration from the norm, or as an 'act of god' that individuals, communities, or businesses are forced to endure [23, 24], and not the result of humans interacting with reliably occurring naturally processes. The use of the term 'natural' itself is misleading and is not intended to imply that disasters are a direct product of geophysical or meteorological processes that are external to human control [25]. The use of the term *natural disaster* is merely to delineate geophysical and meteorological events from contexts of industrial hazards, pandemics, or war and conflict; natural is derived from the process or hazard while the disaster is the result of the interaction of humans with these environmental processes

[26]. Simply put by Okuyama and Chang [27], a '*hazard* is the occurrence of the physical event *per se*, such as earthquake, and *disaster* is its consequence'.

The idea that the destructive nature of natural phenomena are the product of human culpability originates from the Enlightenment and the first modern natural disaster [28]. In a criticism of Voltaire's *Poem of Natural Law: An Inquiry into the Maxim 'Whatever is, is Right'* which discusses the 1755 Lisbon earthquake and Divine Providence, Rousseau, addressing Voltaire, contends:

> Without departing from your subject of Lisbon, admit, for example, that nature did not construct twenty thousand houses of six to seven stories there, and that if the inhabitants of this great city had been more equally spread out and more lightly lodged, the damage would have been much less and perhaps of no account ... How many unfortunate people have perished in this disaster because of one wanting to take his clothes, another his papers, another his money? ... You might have wished... that the quake had occurred in the middle of a wilderness rather than in Lisbon... But we do not speak of them, because they do not cause any harm to the Gentlemen of the cities, the only men of whom we take account.
>
> Rousseau, translation source: [28]

In this, Rousseau describes the first social science view of a disaster [28] – albeit an androcentrist one – claiming that a natural disaster is a social construction predicated on existing cultural norms and by those affected, an idea similar in basis to the theoretical framework posited in Figure 1.1. He also argues that the impacts could be mitigated by methods of zoning, building codes, and rapid evacuation procedures. His arguments derive from his fundamental belief that these impacts were not the act of an unmerciful god, but rather the result of human action [28, 29].

The ideas raised by Rousseau over 250 years ago remain valid today, and have shaped two general schools of thought which are evident in contemporary disaster research: (1) the technocratic or 'Chicago School'; and the later developed (2) social or 'root cause' approach [31]. Derived from floodplain management in the 1940s, the technocratic approach was grounded in the belief that scientific or technological adaptations could be

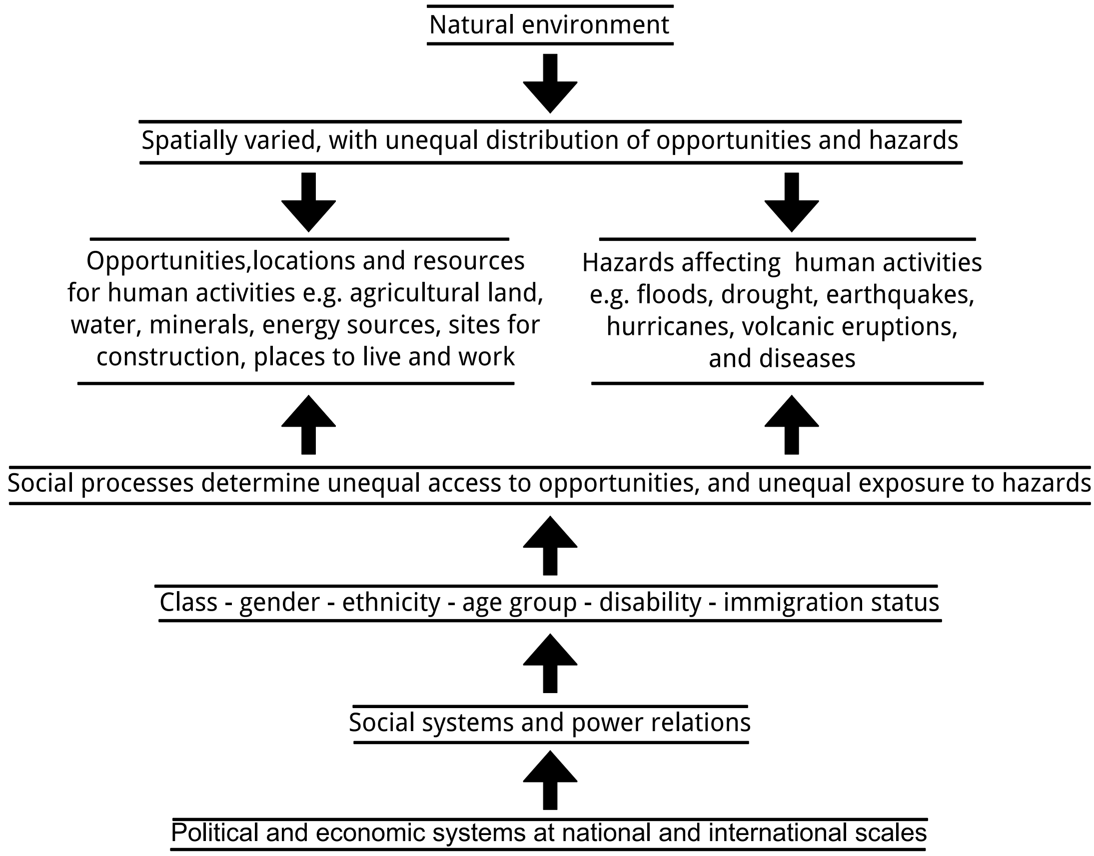


Figure 1.1: Social causation of natural disasters [30].

made to mitigate or limit adverse impacts [32]. However it should be noted that earlier instances of this paradigm being applied in practice are documented in the management of the great Mississippi flood of 1927 by Barry [33]. From the social sciences came the social or 'root cause' approach, which emerged later in opposition to the technocratic approach. It argued that the scientific or technological adaptations only addressed the natural hazard, and that the root cause of a natural disaster was underdevelopment and the marginalized poor [29]. From these two schools of thought has emerged a melded approach, which accepts that the hazard, perturbation, or stressor are naturally occurring, but also acknowledges that the disaster is a consequence of society.

Drawing upon multiple fields of study, a current objective of the disaster sciences is to better understand the relationships between the human-environment interactions by identifying characteristics that make individuals, organisations, or communities less capable of mitigating, enduring, responding, and recovering from the effects of these hazards.

1.2 Natural disaster statistics

The emergence of the melded approach of vulnerability-centred disaster analysis is in response to the increasing costliness of disasters despite the adoption of technocratic solutions [29]. As illustrated in Figure 1.2, the number of people killed in natural disasters has generally decreased, but the number of reported natural disasters, the hazard-related costs and the number of people affected by disasters has risen steadily over time [34]. Since the beginning of the 21^{st} century, on average over 220 million people are affected by some type of natural disaster every year, with approximately 90% of deaths occurring in less-developed nations [34].

As the global economy and at-risk assets have grown, so have the cost of disasters. Although no standard procedure has been established in determining a natural disaster's economic impact, estimates from EM-DAT [34] suggest that from 1970-1979, the average yearly cost of natural disasters was $5.3 billion (USD). In contrast, from 2000-2009, the average yearly costs exceeded $89 billion (USD) [34]. Importantly, these estimates are necessarily low as they are only derived from damage values at the moment of the event, and do not account for longer term impacts. Also, despite the increase in reported natural disasters, there is no evidence to suggest that these increases are due to the natural environment becoming inherently more dangerous. Even taking into account the potential increased frequency and severity of hydrometeorological hazards brought on by anthropogenic climate change [35, 36] does not account for the increase in natural disasters [29]. The increases in natural disaster costs are however positively correlated to wealth (as measured by revenue) and population [37].

To explain the increase, many disaster scientists have taken the position that the root cause of natural disasters lies within human factors such as global population growth, the increased reliance on technologies, and the world-wide shift in preference from rural to urbanized living which has led to the formation of large conurbations. As stated by van der Vink [37]:

> "We are becoming more vulnerable to natural disasters because of the trends of our society rather than those of nature."
>
> pp. 534

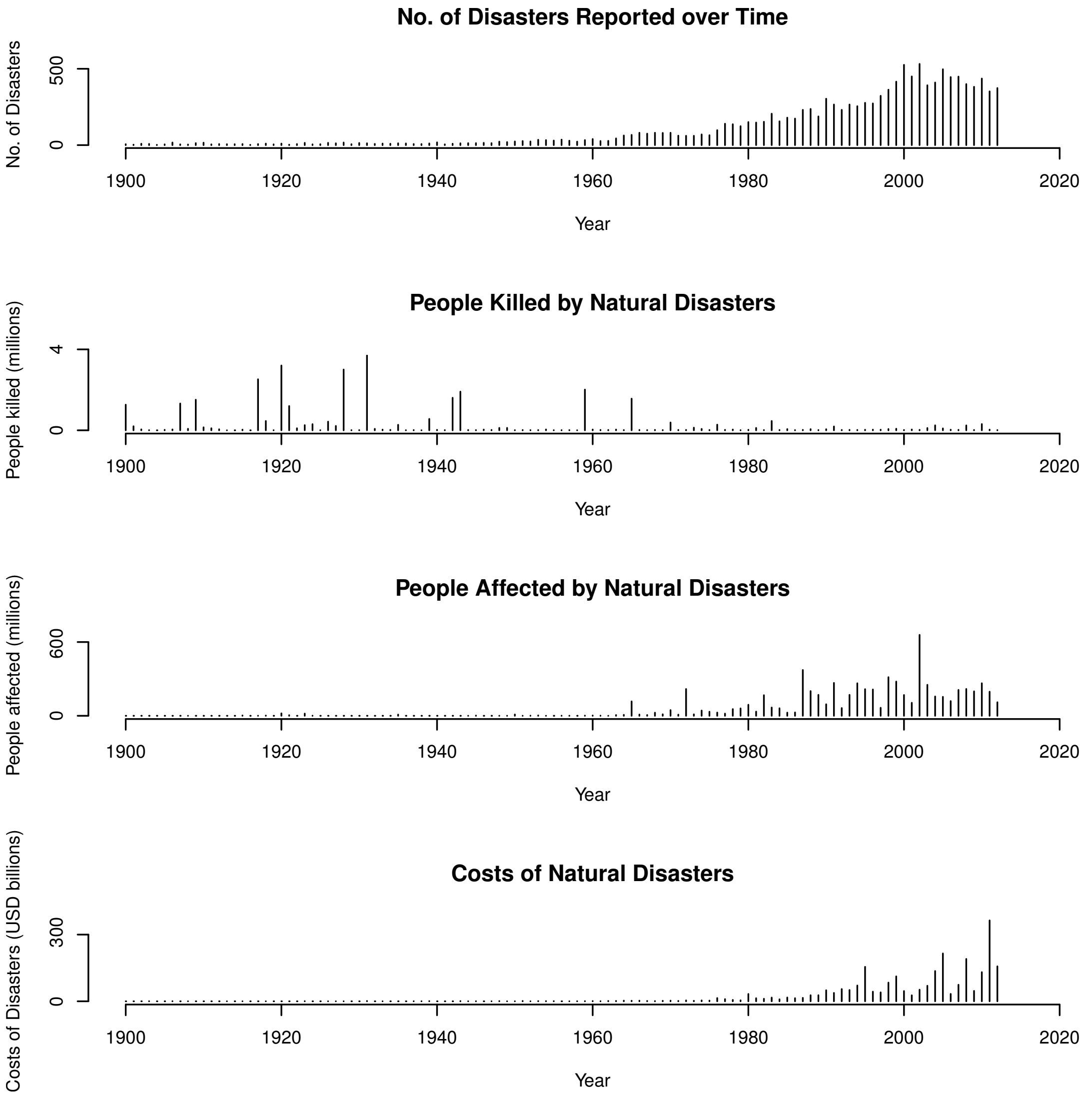


FIGURE 1.2: Estimated number of natural disasters annually and the lives lost or affected worldwide. Source: [34].

Consequently, increasing effort has and is currently being dedicated to determining effective theoretical frameworks from which analyses may better identify the factors that make individuals, enterprises, and societies vulnerable to natural disasters. These vulnerability frameworks integrate both the social 'root causes' of natural disasters as well as the characteristics of natural hazards.

1.3 Vulnerability frameworks

The concept of vulnerability is used across theoretical approaches and consequently different definitions are purposed for different research aims or objectives. For example, vulnerability, using the frequently-cited IPCC definition, "is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change..." [38]. For an analysis of systematic sustainability, Turner et al. [39] defines vulnerability as "the degree to which a system, sub-system or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor." Despite the different accepted definitions, the common elements of vulnerability include the exposure and sensitivity of a system to an external stress or perturbation and that system's capacity to adapt.

The IPCC definition [38] continues to frame vulnerability further in terms of climate change, but it concisely identifies the key themes of vulnerability, which are the stressors to which the system is exposed, the systems' sensitivity to those stressors, and the capability of the system to adapt or cope. Turner et al. [39] introduces the important differentiation of multiple system-scales, as well as the multiple variations on exposure to include perturbations (sudden spikes in pressure; e.g. earthquake), stress (slowly emerging threats; e.g. soil degradation), and stressors (the cause of stress; e.g. drought).

One emergent feature that has been developed from vulnerability research is that the concept has evolved from several different traditions and there exists multiple factors, pathways, or stressors of vulnerability [40]. For example, the human-ecology tradition attempts to identify the underlying themes among these multiple factors and stressors by incorporating the social sciences with the physical sciences and engineering to analyse the system linkages between the physical hazard and the social systems [32, 40, 41]. This framework has demonstrated that natural hazards can have differing impacts on different groups of society [41], and emphasises the importance of economic development in adapting to risk [40]. This argument is counter to the 'Hazards' tradition – largely developed from the technocratic basis – which posits that hazard vulnerability is not necessarily reduced through increased economic activity, and takes a more traditional approach of hazard risk assessment [32]. The 'Pressure and Release' model of hazards builds upon both human ecology and hazards traditions, linking traditional hazard and risk traditions with the human-ecology idea that the system can attenuate or amplify the impacts of a stressor or hazard [39]. The differences between the traditional 'Hazards' approach and the 'Pressure and Release' model is illustrated in Figure 1.3.

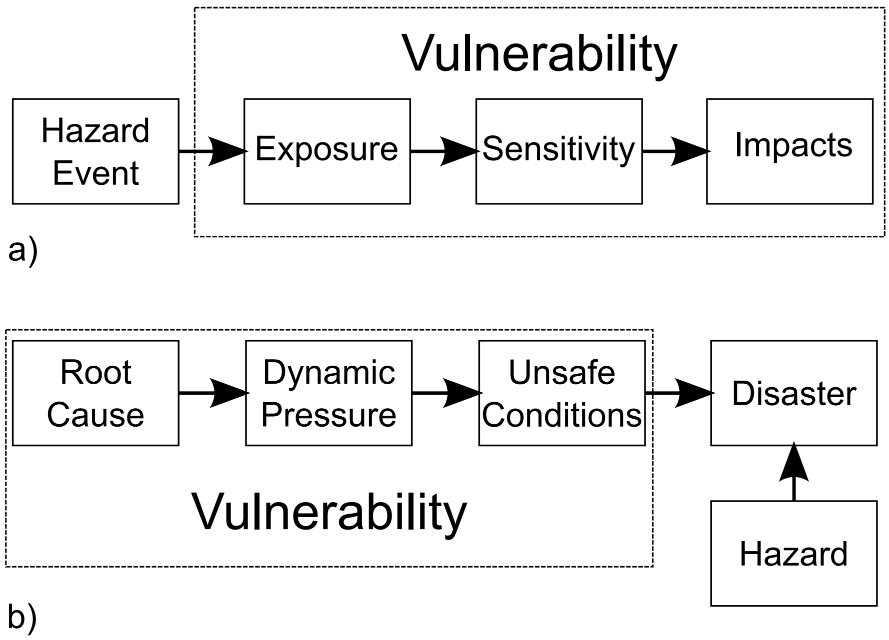


FIGURE 1.3: Illustration of the differences between the traditional 'Hazards' approach and the 'Pressure and Release' framework. Subset a) is a chain diagram of the 'Hazards' approach which begins from the hazard event, with the concept of vulnerability included as an implicit feature of exposure, sensitivity, and the impacts. Subset b) illustrates the 'Pressure and Release model', which begins with the root cause, placing much greater emphasis on the social conditions of exposure and with explicit reference to vulnerability. Source: [39].

In both the 'Hazards' and 'Pressure and Release' frameworks, some inadequacies have led to the development of subsequent frameworks [40]. The 'Hazards' framework does not emphasize the effects of social root causes with regards to the hazards' impacts, making the framework less effective in accounting for variations in outcomes of social sub-systems, or social structures [39]. The 'Pressure and Release' framework accounts for these root causes that are omitted in the 'Hazards' approach, but lacks enough consideration for the coupled human-environmental systems, and lacks specificity on the causality of hazards [39].

The SUST model was developed by Turner et al. [39] to bridge the theoretical gaps between the 'Hazards' and 'Pressure and Release' frameworks. As shown in Figure 1.4, the framework structures the broad processes of human-environmental systems in terms of hazard and component exposures, human and environmental sensitivities, and resilience, accounting and providing feedbacks for both the natural hazard processes, the human and environmental sensitivities, and the systems resilience, which is composed of the hazards' impact, and the affected populations' coping and adaptive capacities.

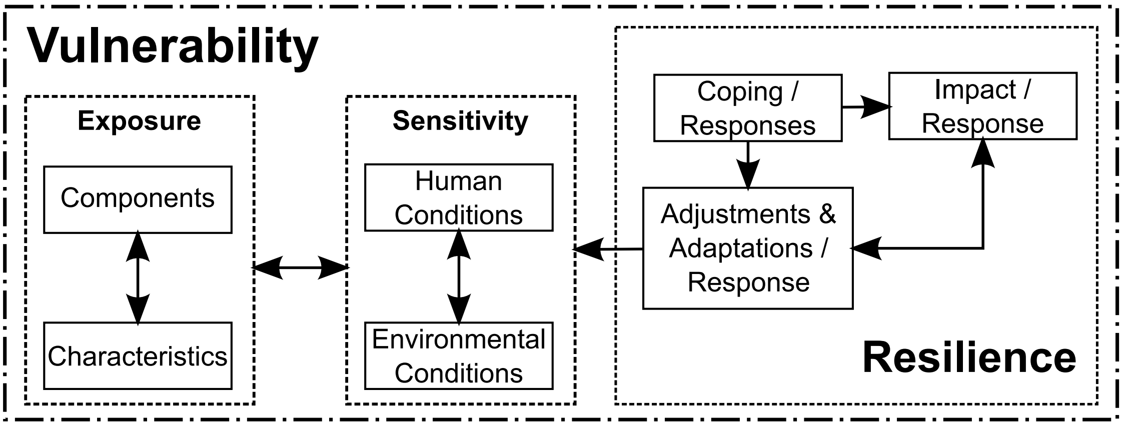


FIGURE 1.4: The SUST theoretical framework of resilience as defined by Turner et al. [39] which incorporates exposures, sensitivities, and resilience in an integrated structure. Components refers to the unit of analysis (e.g. individuals, organisations), characteristics refers to the hazard, human conditions refers to social and human capital, and environmental conditions refers to environmental capital.

Derived from the sustainability sciences and often employed in agricultural studies [42, 43], the purpose of the SUST model is to consider the vulnerability of a system within its greater context by identifying (1) the coupled nature of human and environmental conditions and processes, and (2) the perturbations, stressors and stress that are a product of both human and environmental conditions.

The conceptualization of vulnerability through the SUST theoretical framework is useful as it provides the following generalized lessons:

1. Human and environmental vulnerability are intractably linked;
2. The concept of vulnerability is comprised of several components – namely exposure, sensitivity and resilience – which are coupled and have scalar linkages that increase the variety of outcomes;
3. Scale matters, and similar systems at different scales can be very differentially impacted; and
4. Coupled systems (e.g. individuals and organisations) can have differing vulnerabilities;

These lessons provide a base from which the impacts of natural hazards can be systematically assessed. This is not to say that other traditions are less valid, but rather that the SUST model [39] is suitable in explaining the vulnerability of human-environmental coupling, which as illustrated by the case studies of Turner et al. [42] and Luers [43], is applicable when analysing the effects of stressors on regions populated by primary industry.

1.4 Analysing vulnerabilities

Derived from the Turner [39] model, the factors important to the process of determining the vulnerability of a system to a given hazard and example questions for each are as follows:

1. What are the components being analysed?
    - Is it an individual or organisation?
    - Are they rural or urban?
    - Are they in a developing or developed nation?
2. What are the characteristics of the hazard?
    - Is the hazard a rapid onset event (perturbation) like a storm or earthquake or is it a slow-onset event (stress) like a drought?
    - Does the hazard impact built-infrastructure or soil quality?
3. What are the human conditions (e.g. human/social capital) associated with the component?
    - What are the intrinsic/extrinsic resources available?
    - Are there social biases that make the component more or less sensitive to the impacts of the event?
4. What are the current environmental conditions?
    - Has the environment been recently subjected to an environmental stressor?
    - At what rate would the environment likely recover from the hazard?

5. What is the resilience of the components?
    - How are the components affected by the hazard?
    - What are the coping capacities to the hazard?
    - What are the adaptations to the hazard?

Identifying these specific items is helpful because, as shown in Table 1.1, post-disaster studies have found a wide range of factors that affect vulnerability. Several human condition concepts, ranging from socioeconomic status to rurality, can be relevant in assessing the vulnerability of components (e.g. individuals, communities or organisations) to the effects of natural disasters [41].

TABLE 1.1: Vulnerability characteristics of populations exposed to natural disasters. The '+/-' signs denote the sign of the correlation coefficients or in other words, the directionality of vulnerability to the stated factor. Source: [41]

Concept	Description	Vulnerability (+)/(−)
Socio-economic	Able to absorb losses/enhance resilience with insurance, social, and entitlement resources.	High status (+/−) Low income/status (+)
Gender	Women more challenged than men, due to sector-specific employment/lower wages/family care.	Women (+)
Race and ethnicity	Language/cultural barriers affect access to relief funding/residential locations in high hazard areas.	Nonwhite (+) Non-Anglo (+)
Age	Very old/young are less mobile. Parents lose time/money when daycare facilities are affected.	Elderly (+) Children (+)
Commercial or industrial development	Value/quality/density of businesses sign of community economic health/potential for business loss, and longer-term recovery issues.	High density (+) High value (+/−)
Job loss	High unemployment contributes to slower recovery.	Job loss (+)
Rural/urban	Rural residents more vulnerable due to lower incomes/-more dependent on locally based resource extraction economies (e.g., farming). High-density areas (urban) complicate evacuation.	Rural (+) Urban (+)
Residential property	Value/quality/density of residential construction affects potential losses and recovery. Expensive homes on the coast are costly to replace; mobile homes are easily destroyed and less resilient to hazards.	Mobile homes (+)
Infrastructure and lifelines	Loss of lifeline infrastructure compounds potential disaster losses, and may place large financial burden on smaller communities that lack resources to rebuild.	Extensive infrastructure (+)
Occupation	Occupations, especially those involving resource extraction, can be severely impacted by a hazard event.	Professional (−) Clerical/labour (+) Service sector (+)

Continued on next page

Table 1.1 – continued from previous page

Concept	Description	Vulnerability (+)/(−)
Family Structure	Families with many dependents/single-parent households can have limited finances to outsource care for dependents. All affect the resilience to and recovery from hazards.	High birth rate (+) Large families (+) 1-parent (+)
Education	Education is positively linked to socioeconomic status. Lower education may constrain understanding warning information/access to recovery information.	Less educated (+) More educated (−)
Medical services	Health care providers are important post-event sources of relief. The lack of proximal medical services lengthens disaster relief and recovery.	Higher density of medical (−)

Table 1.1 illustrates the importance of considering sensitivity and exposure of human systems when determining vulnerability. However the studies that Table 1.1 reference, for the most part, refer to post-disaster experiences in developed nations. When comparing across developed and developing nations, the importance of considering adjustments and adaptations is made clear.

For example, less developed nations suffer higher hazard-related deaths compared to wealthier industrialized nations [34]. This is, in part, because wealthier nations have made adjustments and adaptations, specifically by investing in a wide range of practices that decrease the threat to life, including: (1) more robust built infrastructure [44]; (2) stronger regulatory controls and enforcement that ensures standards of quality and can impede housing developments in hazard-prone areas [45]; (3) advanced warning systems capable of detecting impending disasters and alerting the exposed populations [46]; (4) greater local and regional medical capabilities [47]; and (5) social support infrastructure that provides relief assistance that helps decrease hazard-related symptoms [48, 49]. Despite experiencing higher total costs, the larger and wealthier nations generally suffer lower hazard-related fiscal burdens (the proportion of the hazard-related costs in relation to the country's gross domestic product) while the smaller and poorer nations incur higher fiscal burdens [50]. Without the wealth, infrastructure and institutions required for protection against hazard-related deaths, the disenfranchised are generally more vulnerable to the effects of natural disasters.

Table 1.1 also does not convey the important factor that natural hazards are not equally distributed. Certain areas like the Pacific Rim are designated as hazard 'hot spots' due to the wide variety of low- and high-frequency natural hazards faced in the region [50]. Populations located on the Pacific Rim are often exposed to geologic and meterologic hazards simulateously, and investigating these hazards is an area of active development [51].

The types and frequencies of natural hazards can shape historic, economic and political processes, which are factors which can ultimately define how subsequent natural hazards are experienced and their risks interpreted [52]. Such is the case in countries located on the Pacific Rim like New Zealand or Japan, where programs like seismic strengthening initiatives [53] and tsunami barriers [54] proved to mitigate the impacts of the event in some capacity. These programs are examples of adjustments and adaptations that were undertaken to improve resilience to the exposure and sensitivity of human-systems to hazards.

While these adaptations in developed nations are designed to improve resilience, they represent only a constituent of resilience. The concept of resilience is multi-faceted and in using the concept, it is helpful to briefly understand the history of the idea which – like vulnerability – is somewhat complicated and requires discussion.

1.5 The resilience framework

A basis of resilience theory entered the ecology literature in 1973 with Holling [55], who observed a unique domain of attraction in a system which was persistent because of temporally and spatially variable climatically-induced shocks or perturbations. Holling [55] required a description of a seemingly 'unstable' system due to its large fluctuations, but which was persistent as a direct result of those fluctuations. The primary distinction needed was between the concepts of 'stability' and the introduction of 'resilience'. The systems that Holling [55] observed were by definition highly unstable ("the inability of a system to return to an equilibrium state after a temporary disturbance."). However a direct result of these systems' instabilities was that they were extremely resilient.

The breakthrough of Holling [55] was the discovery of multiple ecological system stability-states where in which high variability was an attribute of system persistence, with greater variability existing in more complex systems. The term 'resilience' was used to represent the amount of disturbance a system can withstand without being fundamentally altered into a different stability state [56].

Holling [55] defined resilience within the ecology domain as:

> "...a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables."
>
> -pp. 14

With this definition, Holling [55] had provided an important theoretical contribution from which many disciplines would draw upon, and as a consequence, redefine for differing purposes. The reason for the broad domain-application of the resilience perspective is summarized in the closing remarks of Holling [55], which reads: "The resilience framework ... does not require a precise capacity to predict the future, but only a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take."

The concept of resilience was quickly adopted in the field of anthropology by Vayda and McCay [57], applying the concept to human resilience in an evolutionary context, and directly noting that human societies consciously employ adaptive strategies and behavioural responses to environmental hazards. Vayda and McCay [57] also discuss the challenges of scale within a resilience context, noting that analysis at an individual level "leaves the problem of accounting for the properties of the larger units – populations, communities, and ecosystems." In an especially prescient discourse, Vayda and McCay [57] discuss the implications of the resilience framework, more specifically the adaptive capacity of modern human systems, and identify the benefit of emergent networks post-event:

> "Rapidly forming, transient, and problem-specific groups characterized as a new "ad-hocracy" may represent especially effective strategies in the modern world insofar as the number, novelty, complexity, and unpredictability of the problems faced by individuals and by the business and political organizations to which they belong may be greater than ever before and may preclude effective collective responses by members of permanent social units."

-pp. 301

It was not until the late 1980s and early 90s that the resilience perspective was employed by a wide variety of fields external to ecology [56]. Among those that adopted the resilience perspective, Turner [58] was one of the first to extend the idea to human-environment systems, discussing the resilience of human populations to adverse impacts. Turner [58] draws upon Holling's [55] observation that with increasingly complex systems comes greater system variability, finding greater variations in community factors coinciding with the introduction of greater social complexity, interdependencies and alterations to the physical environment. This conclusion led to the development of several research streams, including risk research by Kasperson et al. [59] which, through a series of case-studies identifies 'critical environmental situations' or 'hotspots' brought on by human-induced environmental change. Kasperson et al. [59] use the concept of resilience to evaluate risk through an integrative approach, drawing on factors such as environmental degradation, population wealth, and the economic and technocratic mitigation strategies available. The work by Turner [58] also led to the theoretical model of vulnerability of Turner [39], which explicitly includes resilience as a constituent factor of vulnerability as previously discussed.

Currently, a generally accepted concept of resilience is the capacity of a system to absorb a perturbation, stress or stressor, while simultaneously adapting without losing the system's original function, structure, or couplings [60]. However depending on the need of research domain, the definition varies; the concept of resilience is not concrete, but rather a way of thinking that provides the basis for inter-disciplinary approaches (e.g. vulnerability research, sustainability science) [61].

1.5.1 The engineering and ecological approaches

From the original definition of 'resilience' and its subsequent adoption into various fields, two broad concepts of resilience have emerged: engineering resilience and ecological resilience [56]. The primary distinction between these two broad categories of resilience conceptualisation is the focus of the definitions and the presence of one or several states of equilibrium. From an engineering resilience perspective, the concept of resilience draws on the more traditional concept of stability, focusing on 'dynamic stability' near a single point of equilibrium or stability state [62]; the resistance to the perturbation and rate of recovery are attributes used to measure resilience [63]. As Hollnagel et al. [62] explain:

> "Success belongs to organisations, groups and individuals who are resilient in the sense that they recognise, adapt to and absorb variations, changes, disturbances, disruptions and surprises – especially disruptions that fall outside of the set of disturbances the system is designed to handle."
>
> -pp. 3

This concept of engineering resilience is often applied to organisational studies as the focus is understanding the capacity of a system's ability to withstand, and persist despite experiencing large perturbations.

Alternatively, ecological resilience focuses on the magnitude of perturbation capable of being absorbed by the system without causing systemic changes [63]. The ecological perspective of multiple states of equilibrium is illustrated in Figure 1.5. From an ecological management perspective, Holling [63] notes that actively maintaining a single stability state can decrease system resilience.

One criticism of the engineering approach is that it does not adequately account for these multiple states of equilibrium, and that it is more suitable for use at the individual firm level in cases where there exists *a priori* evidence and is less applicable for low-probability, high-frequency events [64]. However as Hollnagel et al. [62] argue, from an organisational management perspective, the active maintenance of a system is a requisite propriety of success, and the concept of multiple states of stability is still included within the engineering resilience paradigm, as "it may be the mark of a resilient organisation that it has a number of different modes of functioning whenever a disturbance happens" [62]. These different modes of functioning are considered transitional in contrast to the normal mode of functioning (equilibrium), which is an applicable paradigm in considering resilience from an organisational perspective.

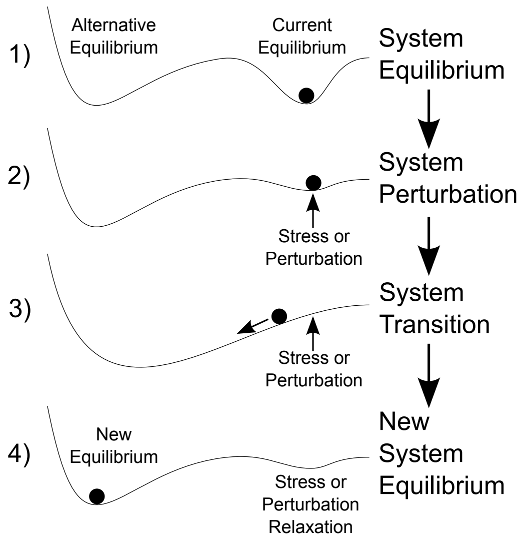


FIGURE 1.5: The ecological resilience concept of multiple states of system stability using a topographic representation as adapted from Holling [55]. The transition from one stability state to another is represented through four stages: (1) is the initial stability state; (2) is the system when the stress or perturbation begins to affect the system stability; (3) is the stress or perturbation forcing the system into a new stability domain; and (4) is the new system equilibrium as the stress or perturbation desists.

1.5.2 Organisational resilience

Prior to the emergence of resilience, organisational research regarding the response to perturbations was developed from a number of fields. Early work by Turner [65, 66] discuss causation of crises, positing that identifiable features or errors are present or accumulate prior to a disaster, and often these disaster-scenarios are the result of poorly constrained epistemic uncertainty (uncertainty that could be known in practice, but is not usually due to a lack of available data). However Turner [65, 66] considered disasters caused by endogenous processes, or institutional failures, and not external stressors such as natural hazards. The field of risk management has, in part, further developed these ideas to exogenic processes or perturbations [64].

Other significant research streams were rooted – or acknowledged – the sensemaking perspective [67], which was an attempt to explain surprises using retrospective accounts, construct meaning, and establish frameworks that mitigate the likelihood of surprises [67]. This often took the form of analysing case-studies of major accidents [68–70] to explain how the accident occurred and what processes would have helped prevent it. The processes and practices used in high-reliability organisations (HROs) were also frequently analysed from a systems perspective for best-practices and their applications for other types of organisations [71, 72].

From an engineering resilience perspective, and similar to research conducted on HROs, organisational resilience looks to identify characteristics that allow for organisations to survive, and even thrive despite experiencing perturbations or stressors [73]. The active maintenance of the resilient organisation, as noted earlier by Hollnagel et al. [62], is a combination of affective, behavioural, and cognitive processes. In terms of the affective and behavioural processes, Hollnagel et al. [74] identify four "essential" abilities of resilient organisations: (1) the ability to respond to regular and irregular threats through both prepared and adaptive manners; (2) the ability to flexibly monitor the system, both internally and externally; (3) the ability to anticipate system perturbations and their consequences; and (4) the ability to learn from these experiences. As noted by Vogus and Sutcliffe [75], two cognitive practices are consistent with those of a resilient organisations: (1) they treat success lightly; and (2) are constantly wary of the potential for unexpected circumstances to arise. In summary, resilient organisations tend to prepare for the unexpected and have the capacity to adapt when unforeseen circumstances arise.

1.5.2.1 Analysing organisational resilience

From these research streams, common themes of organisational resilience are being used to develop organisational resilience frameworks and quantitative assessment methodologies. In the United States, Cimellaro et al. [76] have proposed a four-factor model of resilience, which ascribes to the engineering resilience paradigm, focusing on, among other factors, the rapidity to which the system can return to a single equilibrium. In New Zealand, McManus et al. [77] developed a quantification methodology which yielded a three-factor model of organisational resilience, which include: (1) situation awareness; (2) management of keystone vulnerabilities; and (3) adaptive capacity. Lee et al. [78] analysed and further developed the coherency of these three factors and proposed a simplified two-factor model, which is shown in Table 1.2. The Lee et al. [78] model posits that organisational resilience is a function of both the organisations planning strategies and their adaptive capacity, which are then broken down into five and eight 'indicators' respectively.

Table 1.2: Organisational resilience framework outlined by Lee et al. [78] through an exploratory factor analysis. Note: 'ext.' is an abbreviation for 'external'.

Planning	Adaptive Capacity
Planning strategies	Minimization of silo mentality
Participation in exercises	Capability & capacity of internal resources
Proactive posture	Staff engagement & involvement
Recovery priorities	Information & knowledge
Capability & capacity of ext. resources	Leadership management & governance structures
	Innovation & creativity
	Devolved & responsive decision making
	Internal & ext. situation monitoring & reporting

For the purposes of this thesis, the Lee et al. model was found to be most appropriate. Aside from being developed in New Zealand, the methodology allowed for systematic assessments of resilience, the theoretical framework of which was derived from the engineering resilience perspective. The Lee et al. [78] model was also appropriate for the analysis of individual organisations and therefore can be included for use in the SUST vulnerability theoretical framework.

1.5.3 Definitions of resilience, adaptive capacity and vulnerability

The terms *resilience*, *adaptive capacity*, and *vulnerability* all suffer from polysemy and are frequently referred to in both the literature and this thesis, and it is therefore helpful to briefly define the terms. Vulnerability is a function of the exposure, sensitivity, and resilience of the system to a hazard. [39]. Resilience is the post-event function of those social systems' capacity to rebound, absorb, or recover from disasters [56]. Finally adaptive capacity is the social systems ability to adjust, cope or moderate the changing environmental stressors [79–81], and is influenced by resources such as wealth, infrastructure, social capital and institutions [82].

Organisational Resilience in the context of this study is defined as the ability to survive a crisis and thrive in a world of uncertainty, which is a function of an organisation's adaptive capacity and planning strategies [78]. An *organisation* includes private businesses or firms, not-for-profit organisations, and governmental organisations. This thesis analyses the impacts of naturally occurring perturbations or stressors on organisations through the theoretical lenses of resilience and vulnerability.

The framework of resilience used was developed by Stephenson [83] and Lee [78], which was a derivative of McManus et al. [77]. McManus developed the initial organisational resilience framework from case studies in New Zealand. Stephenson [83] and Lee [78] later developed a questionnaire that assessed an organisation's resilience and through factor analysis, paring down the organisational resilience framework to what is shown in Table 1.2.

1.6 Disaster risk reduction

The purpose of analysing and assessing human-system vulnerability and resilience is ultimately to assist in disaster risk reduction (DRR) initiatives. The United Nations International Strategy for Disaster Reduction (UNIDSR) defines DRR as "the systematic development and application of policies, strategies and practices to minimise vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development [84]". DRR is comprised of two components:

Risk reduction: the effort to reduce the risks brought about by hazardous situations.

Disaster management: the effort to reduce the impacts of a disaster.

DRR initiatives largely began after WWII, utilising military personnel and evolving from Civil Defence approaches to the management of both technological and environmental disasters [85]. From the United States following a technological disaster in 1948 where chemical fumes and a temperature inversion killed 25% of the local population, a joint research proposal by the National Opinion Research Council at the University of Chicago and the Army Chemical Center states:

> ...it is felt that empirical study of peacetime disasters will yield knowledge applicable to the understanding and control, not only of peacetime disasters, but also of those which may be anticipated in the event of another war.
>
> Source: [85]

A major driver of the proposal was the idea that by studying the effects of natural and industrial disasters, the US Military could better predict that likely behaviour of populations during wartime conditions such as bombing raids [85]. As noted by Quarantelli [85], early research on disasters in peacetime was designed to address five applied questions: (1) which disaster elements are most frightening or disruptive to people, and how may these elements be mitigated? (2) what strategies or techniques mitigate fear? (3) what personality factors are susceptible to panic and what factors are related to effective leadership in an emergency situation? (4) what lasting psychological effects of the disaster would affect individual productivity or efforts of disaster control? (5) what types of organized leadership efforts work most effectively in a disaster setting?

Disaster studies in the United States remained militarily orientated through the 1960s, with explicit agendas of identifying how disasters affect peacetime populations and extrapolating those findings to wartime scenarios. The majority of agencies sponsoring disaster research were military agencies, and as a result, it was believed that the military largely dictated research agendas Fisher 1972. However, Quarantelli [85] contends that the sponsoring military agencies did not directly dictate the disaster research area, but notes that the applied orientation of the military sponsorship did have three indirect influences:

1. The conceptualization of a disaster was viewed largely relegated to that of a perturbation (e.g. large, sudden unwarned natural hazard like an earthquake which had influence over a wide area). The concept of stress or stressors went largely unexplored or was overlooked by this framing.

2. The focus on disaster response was framed as an emergency, with rapid solutions preferred, and with relatively little emphasis given to the ideas of recovery, or reduction phases.

3. The heavy focus on planning was derived from empirical studies, and an overall lack of focus on the management of natural disasters.

Beginning in the 1970s, DRR policies and strategies moved away from the applied influences, and began to take a root-cause approach, viewing disasters as having originating from socio-economic and political sources [86]. The DRR framework that has evolved from this perspective and is currently employed is a process of identifying and analysing risks as a means to (1) understand what can happen in the event of a perturbation, stress or stressor; (2) identify whether or not the impacts of the perturbation, stress or stressor in question are acceptable; and (3) identifying and implementing effective and proactive planning or capacity building measures that mitigate the likely effects in a cost-effective manner [87]. However, simply developing these mitigating measures alone is not sufficient; the measures must also be effectively implemented as policy and the risks must be communicated to the necessary stakeholders. The general framework of DRR is shown in Figure 1.6.

The root-cause approach has been widely embraced [86], and as illustrated by disaster statistics shown in Figure 1.2, the implementation of DRR initiatives has made significant steps towards decreasing the loss of life over time, but has not decreased the costs associated, or the number of people affected [88].

FIGURE 1.6: Conceptual framework of disaster risk reduction. Source: [87].

The DRR community focuses on an all hazards approach and – in the past – has had a tendency to focus on technocratic solutions that modify or provide physical protection from perturbations or short-term stresses as a means to decrease vulnerability to human systems. These solutions include levees for flooding conditions or stronger building construction for earthquake exposure. Traditionally, DRR projects have involved:

- risk and hazard mapping;

- geophysical studies;
- climate studies;
- data collection instrumentation deployment and networking; and
- early warning systems.

These traditional solutions often proved moderately effective in providing short-term protections and an improved understanding of the hazards (perturbations and stresses). As a result, high-frequency events (e.g. meteorological) are now forecasted with relatively high levels of confidence at time-frames applicable to the communities likely to be affected [89]. The well populated historical record also provides communities with a wealth of personal or anecdotal references to draw upon [90]. However, even with a well-populated historical record, examples of technocratic solutions failing, or actually increasing hazard vulnerability are not difficult to find [33, 91].

A consistent challenge to the traditional DRR approach is constraining risk uncertainty through limited available data and resources. From the decision sciences, risk is a function of (1) the likelihood of the hazard occurring and (2) the value of the resulting losses from the hazard [92]. However this conception of risk is complicated in the case of natural disasters by uncertainty (be it epistemic or aleatoric: epistemic being systematic uncertainty and aleatoric being statistical uncertainty); the likelihood of a hazard occurring and the value of losses are often poorly constrained – especially in the case of low-frequency events such as large-magnitude earthquakes [25, 93]. For example, in most cases earthquake recurrence intervals exceed the average human lifespan. The nature of the impacts on built infrastructure is modelled probabilistically due to the relatively high levels of aleatoric uncertainties [93]. Additionally, the value of losses consists of the relatively quantitative economic and organisational costs (such as the costs of a catastrophic building loss), as well as the less quantifiable social and psychosocial costs [30].

In the case of low-frequency hazards such as earthquakes, long and variable recurrence intervals and the limited historical record creates high levels of uncertainty for modelling purposes. Engineered solutions, such as seismic strengthening building initiatives and tsunami barriers, can reduce the impacts of a low-frequency hazard's impacts to an extent. Following the 2011 M_w 9.0 Tōhoku earthquake that occurred off the east coast of Japan and the resulting tsunami that followed, buildings performed relatively well in resisting the ground shaking [94], but some tsunami barriers were too low for the swell – which in some areas exceeded 20m – and coastal towns and land suffered catastrophic losses [95]. Additionally, the cost of engineering solutions – like 20m+ tsunami barriers – can be prohibitively high, even for wealthy nations. The high degree of uncertainty and the high costs associated with constructing expensive technocratic protections, such as tsunami barriers, make the likely resulting impacts of the event more uncertain, even in the context of a tectonically active region with relatively frequent exposure to low-frequency hazards [96, 97].

Despite the relatively high level of uncertainty regarding the probable degree of impacts caused by physical processes or perturbations, the causes or physical processes of perturbations or stressors (e.g. storm, earthquake) are still better understood than the human consequences [30]. As a consequence, there has been a notable expansion in focus from a perturbation or stressor centric approach to include underlying root causes [88]. Work by Kreimer and Munasinghe [98] called for DRR to expand focus to include analysis of root-causes, and in 1994, the *The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness, and Mitigation and its Plan of Action* institutionalised this expansion. Also known as the "Yokohama Strategy", the strategy shifted focus from a response-based approach to a more proactive one that included DRR within development planning and policy. In 2005, the Yokohama Strategy was replaced by the Hyogo Framework [99], which was established five action items:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
2. Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
3. Identify, assess and monitor disaster risks and enhance early warning.
4. Reduce the underlying risk factors.
5. Strengthen disaster preparedness for effective response at all levels.

The intended outcome of the Hyogo Framework [99] was stated as: "The substantial reduction of disaster losses, in lives and in the social, economic and environmental assets of communities and countries." In addressing the intended outcome, the Hyogo Framework identifies the importance of social vulnerability constructs and benefit of empowering local communities or organisations to take proactive disaster risk reduction measures among other factors [99]. While there is still much focus in better understanding the hazard processes, since the Yokohama Strategy, there has been an increased focus on closing the gap between the state of knowledge between the causes and consequences of natural disasters [2, 88].

Disaster risk reduction now seeks to improve vulnerability assessment methodologies that better constrain the relationship between disaster impacts and root causes [100]. Current DRR seeks to integrate:

- Resilience and vulnerability frameworks;
- Regional vulnerability measurement methodologies; and
- Meta-analysis of vulnerability.

However the integration of these items is often limited by the limited availability of study-specific data collected using a variety of methodologies. While the ability to accurately forecast a natural disaster has improved over time and is useful in alerting the community, the risk, impact, and costs of a natural disaster are unconstrained without accurate impact data. There are initiatives to standardize impact assessment methodologies (e.g. IRDR's FORIN method), however currently no uniform impact (social or financial) assessment methodology exists for multiple disasters across different nations [101].

1.6.1 Economic impact studies

Early multi-hazard economic impact studies using aggregate metrics, such as Friesma et al. [102] and Wright [103]) found that natural disasters have little measurable affect when compared to underlying social forces and macroeconomic trends. Others have found that natural disasters have the capacity to accelerate existing business or organisational performance trends [104]. Some have argued that natural disasters can bring economic windfalls to the region during the recovery phase, however many argue that this perspective is a common economic misconception, and the total regional and community losses tend to outweigh any short-term economic stimulus effect caused by a disaster event [101].

More recently, studies such as Rose [105], Brookeshire et al. [106], and Cochrane and Olson [107] further developed large-scale studies to include sectoral scale input-output analysis that were useful in understanding the regional and national scale implications of natural disasters. However, as Kroll [3] notes, the scale at which economic analyses were performed following the 1989 Loma Prieta earthquake led to differing results which outlined the need for organisational-level studies.

In improving the economic modelling of natural disasters, the most predominant advancements have been made in empirical data collection of disaster damage and loss analysis, largely from multidisciplinary research [108]. These multidisciplinary studies such as Tierney [109], Alesch [110], and Chang and Falit-Baiamonte [111] provide the needed empirical impact and response data of affected organisations in a disaster setting.

Consequence data collected and analysed through these multidisciplinary lenses are then incorporated into high-level scenario-based modelling initiatives. HAZUS, in the United States [112], and Riskscape in New Zealand [113], are two examples of scenario modelling initiatives that use hazard exposure data to develop a likely natural disaster scenario, and deduce the consequences of exposed assets. In both models, a simulated hazard based on empirical or theoretical data is projected over the region's built infrastructure and communities to identify and inventory what and who are exposed. The built infrastructure and communities' capacity to withstand the effects of the hazard are then assessed using probabilistically derived models called fragility functions [114]. These fragility functions are used to provide a regional estimate of the likely consequences a hazard would have given that region's level of exposure. One challenge in this method is deriving accurate fragility functions, which require a large amount of data, and as a result, collecting impact data for the purposes of fragility functions is an area of active development.

Simulations of natural disasters have also yielded empirically derived evidence that is useful in modelling or forecasting the likely effects of natural disaster. Scenarios such as ShakeOut in the United States [115], and New Zealand [116] identify disruptive factors external to the physical damage of built-infrastructure, and business interruption losses often continuing well after the disaster has 'stopped' [115].

1.6.2 Disaster assistance

The effectiveness of disaster recovery assistance is currently a subject of debate, with different studies showing different results. For example, in the United States, monetary disaster assistance has been shown to be successful in aiding the recovery of individual households following a major hurricane or earthquake [6]. However, the same study showed that monetary disaster assistance was unsuccessful when provided to organisations [6]. Organisations proved more dependent on regional economic conditions for long-term survival, and were merely temporarily bolstered by short-term cash injections, failing shortly after the assistance was removed [6]. On the other hand, FEMA mitigation grants in the United States have shown relatively good cost-benefit ratios for flood and wind damages provided these grants are implemented before the disaster occurs [117].

In the case of family-owned businesses, again in the United States, post-disaster assistance across a variety of disasters have been shown to improve organisational resilience if the business was female-owned, and decrease resilience if male-owned [118]. Of the male-owned businesses in the study, 25 per cent were part of the agricultural sector, while only 5.7 per cent were female-owned agricultural businesses [118]. While these conclusions may be superficially applicable as many agricultural organisations in New Zealand are family operated, the cultural differences between the United States and New Zealand may challenge the reliability of these findings. In general, for many small to medium sized farming organisations, the delineation for organisation and household can be muddled; currently, there has been no formalised analysis linking survival of farming organisations and the receipt of rural assistance payments following a natural disaster.

1.7 Organisational responses to natural disasters

As illustrated in simulations such as ShakeOut, the level of damage sustained by an organisation is not an accurate proxy for that organisation's ability to survive following the disaster. Although a tenuous statistical relationship has been found between the level of physical damage and business survival following earthquake disaster, a variety of organisational characteristics can have an even larger influence on the level of disruption felt by the organisation [7, 110]. Some of these characteristics include an organisation's cash flow, product diversification, supply chain networks, pre-existing socio-economic circumstances, and/or management style amongst others [119–121].

Previous work following large scale earthquakes and hurricanes have found that business survival can be affected by a number of different factors such as the number of employees, type of organisation, demographic of owner or management, the industry sector, and location [122]. However, the majority of work being done for organisational survival following natural disasters does not specifically focus on farming organisations. Consequently, many of the organisational metrics such as the age of the organisation or the number of employees do not behave similarly in the agricultural sectors. For example, the literature has identified that small to medium sized organisations are more likely to remain closed following a disaster [123]. Spatial analysis has shown that organisations in dense urban areas are more likely to fail [124]. However, these relationships are based on studies of small to medium sized enterprises (SMEs) in urban environments that were more likely to occupy unreinforced masonry buildings [110, 125].Therefore, these conclusions are not useful when considering rural organisations in a multi-hazard context and the conclusions from these studies are not applicable when modelling rural organisational resilience post-disaster.

In many circumstances, older organisations, which are likely to employ more staff than younger organisations, have been shown to be more capable of survival following a natural disaster [8, 110]. However, many farming organisations have existed within families for several generations without significant employee expansion or physical growth and therefore would not fit the survival model observed in previous circumstances.

Recent studies have found that organisational, sectoral, and economic health may be more applicable to understanding the resilience of farming organisations. For instance, economic trends experienced prior to a disaster can be exacerbated in the aftermath, and other market adjustments following a disaster can have major implications for disaster survival [110, 111, 120]. As an example, commodity price increases resulting from decreases in market supply could help offset some of the revenue losses sustained during a natural disaster but only in a scenario where stock or crop losses are sufficiently large enough to lower overall market supply [126]. Circumstantial conditions prior to the disaster allow for some organisations to capitalize on natural disaster conditions. Farms that accumulate abnormally high levels of feed due to lower prices may have greater opportunity during a drought or snowstorm. On the other hand, farmers can leverage the disaster's conditions favourably if they can access critical resources quickly. During the 2007 to 2009 drought in New Zealand, farmers that purchased cheap store stock or discounted stock were able to use the drought conditions to turn a profit [127].

1.8 The rural New Zealand Context

Located on the Ring Of Fire just above the roaring forties, New Zealand's rural organisations are exposed to a range of tectonic and meteorological hazards. The natural hazards include wildfires, floods, landslides, tornadoes, volcanoes, cyclones and severe weather events, and earthquakes. In terms of high-frequency events, New Zealand as a sub-tropical island nation is routinely affected by extreme weather events. The low-frequency events include earthquakes, landslides and volcanic activity. Because New Zealand is located on an active plate margin, there are several major earthquake events in the historic record. These include a M_w 8.2 in the North Island in 1855, a M_w 7.8 in the South Island in 1929, another M_w 7.8 in the North Island in 1931, and a M_w 7.1 earthquake in the South Island that occurred in 1968.

In September 2010, both a major earthquake and snowstorm occurred in two regions of the South Island. On the 4^{th} of September, the M_w 7.1 Darfield earthquake initiated what would become to be known as the Canterbury earthquake sequence, which consisted of subsequent earthquakes such as the M_w 6.3 February 2011 earthquake, the M_w 6.3 June 2011 earthquake and several thousand aftershocks of M_w 4.0 or greater. On the 18^{th} of September 2010, an unseasonably late and severe cold weather storm impacted the Southland region, killing several thousand livestock in the region and collapsing structures in the city of Invercargill. Both the 2010/2011 Canterbury earthquake sequence and the 2010 Southland snowstorm directly impacted the rural areas of New Zealand, small rural communities, and regional farming organisations.

In New Zealand, impact studies of low-frequency, high impact events – excluding earthquakes – have observed the direct impacts of the event and have identified on-farm vulnerabilities to these threats [128, 129]. Impact assessments to localized weather events such as snow, drought and rain in New Zealand have either focussed on collecting organisational impact and network effects or on-farm psychosocial data [14, 130, 131]. There are limited examples of studies in New Zealand that have compared the impacts of different natural disasters on farming organisations [11], or that have utilised both qualitative and quantitative data collection methodologies in concert as a means to define the overall impact of the event.

1.8.1 Farm-specific vulnerabilities and resilience in New Zealand

Rural areas are generally considered to be more vulnerable than urban areas due to the lower average earnings of rural populations, the high level of exposure to natural hazards, and the lack of resources readily accessible [132, 133]. In many highly developed countries, the diversification of the urban employment market and lack thereof in the local rural markets have led to population decreases for many rural communities [134–136], and natural disasters further accelerating these trends [137].

Studies in both the United States and New Zealand have found that the decreased community services in rural areas inhibited the community's sustainability [14, 138]; the closure of essential organisations in rural communities directly contribute to rural population decline [139]. Furthermore, rural organisations show high levels of interdependencies between the local community and business populations [12], and decreases in productivity in one sector, most notably the agricultural sector, can have negative implications for the other local industries [18].

Rural organisations in general tend to consist of few employees [140, 141], with a significant percentage consisting of only one employee [142, 143]. Small rural organisations have been generally viewed as more vulnerable than their urban counterparts [144] with rural communities offering smaller localized markets [145] and are therefore more sensitive to changes in their customer bases. However, studies have also shown rural organisations to be less affected to economic downturns [145, 146], and more responsive, flexible and resilient to crises [141]. That said, there exists a high degree of interdependencies in the local rural economies, and downturns in one sector can have negative and compounding effects for others [18].

Much of what is known regarding the vulnerability of farming organisations to natural disasters is derived from high-frequency meteorological hazards. These hazards include droughts, floods, and snowfall, and are likely to increase in frequency and intensity in many parts of New Zealand as a result of climate change.

Despite occurring relatively frequently, these meteorological events can be very destructive. Flooding events can destroy stock, farm infrastructure and paddock growth. Drought conditions often force many sheep and beef farmers to liquidate assets prematurely to maintain cash flow, which leads to lower stock numbers, lower production levels and weaker financial positions for multiple seasons following the event [127]. Dairy farms are not immune to droughts, and in some cases may be more impacted by dry conditions. Livestock farming (dairy, beef, sheep, etc.) organisational health is also heavily influenced by commodity price conditions. Overall, storms are problematic for farms for a variety of reasons that can be seasonally dependant and difficult to generalize.

The agricultural sector in New Zealand is also exposed to a range of low-frequency events which are difficult to predict, that can impact operations and more importantly significantly decrease the resilience of many organisations within a large geographic region and a short period of time [78, 120, 147, 148]. Low frequency, often high consequence events such as earthquakes, have the capacity to cause significant physical damage, disrupt critical service delivery, halt or slow production for extended periods, affect cash-flow, and psychosocially affect staff and family. These effects increase the vulnerability of farming organisations, and pose a significant threat to organisational health and resilience as drops in revenue weaken cash flow and lower overall return on investments [119]. One impact that has been observed across multiple types of events is the potential for significant psychosocial impacts on the farmer and their family [13, 149, 150].

Due to the nature of farming, farm vulnerabilities change depending on the time of year and are primarily driven by weather and climate [128]. As a consequence, weather and climate related impacts are major drivers behind the majority of risk management practices for farming organisations in New Zealand. The concept of resilience is commonly understood to be in reference to an organisation's ability to mitigate the impacts of climate change [151]. For farms, low frequency-high impact natural events are categorised by the Ministry of Primary Industries as 'Acts of God' and as such are not identified as events with significant elements of control [152]. Hazard mitigation plans are typically designed around frequent climatological potentialities while ignoring low frequency-high impact events. However, as evidenced by the Canterbury earthquake sequence, low frequency-high impact natural disasters can significantly affect farming organisations and therefore farm risk management planning must consider mitigation techniques for these potentialities [151].

1.8.2 On-farm resilience to disaster-related impacts

The impact a disaster will have on farm and rural non-farm organisations is dependent on the individual sector's vulnerabilities, pre-existing organisational health, and the resilience of these organisations (i.e. how well they are able to cope when faced by hazard events) [78, 111]. Work by Smith [119] and other authors highlights the significant differential impact climatic and geological hazards may have to a rural farming household, but stop short of analysing indicators which estimate farm resiliency to such external shocks.

Informal support networks in rural communities are showing signs of stress [119]. Rural communities have undergone significant structural changes as rural populations have shown consistent population declines. Farming organisations are increasingly reliant on professional services rather than neighbouring farms, and the life-styler (hobby-farmer) demographic continues to grow in size [14]. This re-orientation of the rural community demographics has occurred in concert with a general decline of community facilities such as post offices, police stations, and schools. This decline in community spaces has potentially lessened the strength of informal networks, further decreasing rural organisational resilience to natural disasters [14].

Smith [14] concludes that rural societal structures play a critical role in rural organisational resilience. This inter-organisational and social collaboration challenges the neoclassical economic paradigm identifying competition, profitability and lowered costs as the principal factors influencing organisational resilience [14]. It is clear from Smith's research that neighbour relationships increase organisational resilience, and direct competition between neighbours may potentially lower the resilience of both organisations and the rural community [153].

Farming organisations' experience with natural disasters does not necessarily improve the organisation's resilience. The frequency, and consequently the familiarity farms have with droughts in the United Kingdom (U.K.) has been identified to decrease the financial impacts of the event as some cropping farms were able to adapt to these effects [154]. During successive droughts occurring between 1975 and 2006, this trend was apparent for potato, wheat and oilseed rape farming, while no pattern of adaptation existed for sugarbeet and barley farming [154]. For livestock farming, much of the immediate impact of the drought was offset by farmers selling off additional stock to maintain cash flow, leading to overall decreases in production for the years following. This fact obfuscates the estimates of financial impacts from the drought, thus making it difficult to fully understand the evolution and adaptation of U.K. farmers to drought effects [154].

During the 2007-2009 drought in New Zealand, sheep and beef farms responded in a similar manner to that of the U.K. farmers [127, 154]. Although the value in livestock declined, the impact on cash flow was complicated by the sale of capital stock and reduced purchases of stock, which lowered production for the season following [127].

In both the U.K. and the New Zealand drought examples, the use of insurance was not a commonly reported mitigating or coping strategy. Although the business literature has identified insurance as a primary risk transference mechanism that can mitigate losses sustained during a disaster [118, 155], in some circumstances insurance is not applicable to the agricultural sector. Much of insurance coverage is in reference to structural and contents damage, which does not cover significant assets for farming organisations such as land, soil and livestock. Insuring livestock in the event of an earthquake is typically not an insurable or viable option for many farming organisations. Some farms may opt to cover stock in the case they escape and are hit by a vehicle, but insuring stock in the case of a natural disaster does not appear to be common practice. In Southland following the September adverse weather event, stock loss coverage was made available in limited numbers by one major insurer and the uptake on this package was lower than expected due to a wide variety of reasons. Government subsidization of crop and flood insurance in the case of adverse weather events has been identified to present a moral hazard and may ultimately decrease farm resilience as risk transference decreases potential losses to the farm, allowing for the development of sub-optimal or high-risk areas that are likely to be affected during an event [155, 156].

1.8.3 Changes to farming organisations in New Zealand

In the mid-1980s, the New Zealand government undertook rapid policy changes in favour of deregulation [157], instituting macro-economic reforms such as floating the exchange rate, removing import licenses, and dismantling protections for the agricultural sectors such as subsidies, price controls, tax breaks and other financial incentives [158–160]. These neo-liberal policies changed the agricultural industry substantially, as with these changes farmers received effectively no subsidies [161], and services that were previously provided for at no charge had to be purchased, which included farm-management consultations [159]. However despite the specific targeting of the agricultural sector by these policies, some have argued that the non-agricultural measures had a stronger impact on the farm economy, citing the dollar increase and the sharp increase in interest rates [159, 162].

It has also been argued that the neo-liberalization of the New Zealand economy and the removal of farming subsidies have led to more sustainable farming practices by removing the incentive for farmers to develop marginal areas for production [163]. One by-product of the economic policy reforms is that it penalized farmers with high debt-loading - typically younger or new to farming, and very large operations - while not affecting older, generational farmers as heavily [159, 160]. This consequently skewed the farming demographic significantly, as interest rates increased from 10% to 25% over a two year period [159].

The removal of subsidies for disaster relief to New Zealand farmers may have increased sheep and beef farms' resilience to severe weather as they have improved stocking policies to accommodate their increased risk exposure [163]. However, Smith [160] has argued that the removal of farm subsidies did not address fundamental concerns about organisational risk exposure, such as declining social networks, while increasing firm and industry exposure to fluctuations in commodity prices driven by international markets. Alternatively, it has been argued that on-farm best management practices incorporate environmental issues, including natural disasters, regardless of subsidization levels [164], and therefore sustainable farm management and resilience may be more related to the individual farmer than to that of subsidization levels.

Following the 1984 subsidy removal, farming organisations have increased in size with the help of improved access to technology, and new agricultural practices. As a result of improved farm technologies, the modern New Zealand farmer relies less heavily on farm labour forces. The overall number of farms in New Zealand has dropped by 20%, from 80,376 in 1999 to 63,336 in 2007 [165]; the majority of the decline is attributed to farms of 600 hectares or smaller. The number of farms larger than 600 hectares has increased, with the number of farms greater than 4000 hectares increasing by 10% during the 8 year period [165]. Additionally, the agricultural sector has seen a general decrease in sheep numbers of 25% while the number of dairy cattle has increased by 20% during the same time period [166]. However, the number of sheep farms, beef farms, and dairy farms larger than 200 hectares have shown increases of, on average, 152%, 257%, and 133% respectively [165].

Farming organisations that derive over 50% of value from multiple sources have become less common across all organisational size demographic groups, indicating that specialization has increased [165]. These general trends indicate that efficiencies have increased as larger, more specialized farms are optimized to service the markets. Farming organisations in New Zealand have shown increases in size and technological implementation, and as a result of these changes, the resilience characteristics of these farms have changed over time.

New Zealand's agricultural sector has been and will continue to represent a significant portion of the economy [167]. Locally, farming organisations have strong linkages to the rural economies through their support of service organisations and creating opportunities for supporting industries [168]. The fundamental base of the agricultural sector is comprised primarily of small to medium sized farms that supply a wide variety of secondary producers who service domestic and international markets. In fact, the majority of goods produced by the New Zealand agricultural sector are delivered to international markets [167] making them a significant earning of foreign exchange for New Zealand. The primary producers are exposed to international market volatility due to New Zealand's pronounced neo-liberal economic policy towards the agricultural sector, with the lowest levels of subsidization among the OECD countries [160]. Due to the significance of the sector economically, and the range of climatic, geological, and economic exposures faced by these small to medium sized farming organisations, natural disasters can have significant, immediate and far reaching network impacts for local rural communities, secondary producers, and the New Zealand economy.

1.8.4 New Zealand farming assistance

While the official position of Ministry of Primary Industries (formally the Ministry of Agriculture and Forestry) identifies that "... [r]ural individuals and communities remain primarily responsible for their response and recovery from adverse climatic and natural disaster events, assistance following declarations of adverse events is made available when events exceed a community's capacity to cope" [169]. In some cases, governmental assistance is provided to assist the families of the affected organisation. In other cases, governmental assistance directly benefits the organisation by providing volunteer labour. All the assistance programs are designed to benefit the rural community as a whole, and the stabilisation of these rural organisations is integral to maintaining a vibrant and sustainable rural community.

Adverse weather events and disasters are ranked into three general categories: small-scale events, medium-scale events, and large-scale adverse events. The level of the event is determined based on a 5-criteria matrix as shown in Table 1.3.

Table 1.3: Event scale matrix qualities and defining characteristics for governmental response.

		Assessment/classification of the event		
Themes	Criteria	Small	Medium	Large
Risk Management	Avail. of options	Readily	Moderately	None practical
Event Magnitude	Likelihood	Freq.	Infreq.	Rare
	Physical	Local	≧District	≧Regional
Capacity to cope	Economic	Local	≧District	≧Regional
	Social	Local	≧District	≧Regional

The severity of the event declared defines the level of assistance available to rural communities. For small-scale adverse events, assistance for businesses is relegated to tax flexibility and pre-mature liquidation of assets deposited in an income equalisation scheme. Rural assistance payments are made available for the families of affected farms. Relief options for individuals are available for those who lost employment due to the event and do not relate to organisations.

Following medium-scale events, grants are made available by the Ministry of Primary Industries (MPI) and the Ministry of Social Development (MSD) to Rural Support Trusts which are used to provide financial advice and welfare support to farming organisations [170]. Enhanced Task Force Green is made available to provide financial assistance following a natural disaster. There is also a one-off grant provided by the MSD that is designed to assist families in permanently leaving commercial farming. MPI funds volunteer labour costs and also provides assistance for education and information dissemination following the event. This assistance takes the form of media communications and technology transfer grants which are designed to provide technical advice and education to affected farmers on recovery options. These response and recovery initiatives may be coordinated by a MPI appointed Agricultural Recovery Facilitator.

In the case of large-scale events, the government has the option to provide, in addition to the suite of medium-scale recovery measures, a Special Recovery Measure (SRM). The SRM is designed to restore uninsurable damage to land-based organisations at a reimbursement rate of 50 per cent. The SRM is not designed to aid urban organisations, a policy which is predicated on the assumption that urban businesses have fewer assets that are uninsurable.

1.8.4.1 Rural Support Trusts

Rural Support Trusts (RST) are charged with coordinating the initial response to adverse weather events or periods of hardship, assist farmers in making informed business decisions, advocate on behalf of farmers for financial assistance, and provide information and services for stress relief. RSTs are comprised of local members of the rural community that have strong network relations in the area. They liaise with governmental and non-governmental organisations that have resources and capacity available to assist rural organisations. RSTs operate as a contact point for farmers all year, with Freephone numbers and websites that provide daily alert updates for the region.

RSTs liaise with a variety of organisations to coordinate relief efforts by establishing a board of directors to develop relief options. This board consists of members from Federated Farmers (a group that essentially acts as a national-level union for farmers) and other industry associations, regional or district councils, governmental agencies such as Work and Income or Inland Revenue, Industry goods organisations such as Meat and Wool NZ, Dairy NZ, HortNZ amongst many others, Civil Defence Emergency Management groups, social support organisations such as Rural Women New Zealand along with other organisations related to the industry such as veterinarians, stock agents, and banks.

1.8.4.2 Task Force Green

Task Force Green (TFG) and Enhanced Task Force Green (ETFG) are programmes operated by the Ministry of Social Development that are designed to provide project-based employment to the local population who are receiving government financial assistance and are at risk for long-term governmental dependency. The major difference between TFG and ETFG is the level of subsidization provided by the central government, with the former being partially subsidized and the latter being entirely subsidized. The projects used for TFG and ETFG must be of benefit to the community and must not displace existing staff. TFG is available following a small-scale event while ETFG is only available following medium and large-scale events.

1.8.4.3 Rural Assistance Payments

Rural Assistance Payments (RAPs) assist farming organisations for a fixed period of time following the event of a declared state of emergency or adverse weather event such as natural disasters, flood or drought. The RAPs are bursaries designed specifically for the farmer's household living expenses, and may not be used to make organisational purchases. Rural Support Trusts actively seek out potential candidates for this relief.

TFG, ETFG and RAPs are not complete representations of the disaster relief options available to rural organisations, but are to be viewed as common examples of governmental disaster relief.

1.9 Thesis goals and objectives

The aim of this thesis is to present the impacts of two disparate types of natural hazards on both farming and rural non-farming organisations in New Zealand utilizing a combination of qualitative and quantitative impact assessment methodologies. This thesis presents results from the Canterbury earthquake sequence while also presenting results from 2010 Southland snowstorm to contrast the earthquake-related impacts against the organisational impacts from a more commonly occurring and studied natural hazard.

The research investigates the vulnerability and resilience of organisations through the assessment of the impacts of both disasters, the organisational responses to those impacts, the greatest challenges faced during and following the event, and the financial implications for affected organisations. It is intended to provide both quantitatively and qualitatively derived empirical evidence that frames the impact, response and recovery of rural organisations to two fundamentally different types of hazards. The objectives of this thesis are as follows:

- Catalogue, and analyse the types of impacts incurred and recovery strategies employed by farming and rural non-farming organisations during the Canterbury earthquake sequence and the 2010 Southland snowstorm;
- Identify the factors that proved most disruptive for farming and rural non-farming organisations during both events;
- Identify the factors helpful in mitigating the effects of both disasters;
- Determine what effect the disasters had on the organisational performance levels; and
- Analyse the use and effectiveness of the governmental assistance programs and volunteer labour in supporting rural organisational recoveries.

The conceptual framework of this thesis employs the Turner et al. [39] vulnerability framework which inherently includes the engineering resilience approach as described by Hollnagel et al. [62] previously. The disaster risk reduction approach is used in supporting the overall vulnerability approach, most specifically in the development of rural organisational fragility functions. While the vulnerability framework provides the overarching framing, the use of the different frameworks varies from chapter to chapter depending on each chapters' objectives; all three approaches are drawn on heavily throughout, and are used in concert to provide complimentary forms of analysis. This is most starkly exemplified in comparing Chapters 5 and Chapter 7, which focus more heavily on vulnerability and DRR approaches respectively.

This thesis uses questionnaire-based social surveys (standardized forms designed to capture structured information from a targeted sample population [171]) which have proven effective in gathering descriptive and analytic data that help provide some insight into how organisations are affected by natural hazards [109, 111, 172], and what factors are important to those organisations' survival [173]. To date however, very few studies have catalogued or analysed the effects of an earthquake on rural organisations. The overarching objective of this thesis was to fill this gap by providing empirical data and analysis regarding rural organisational vulnerability and resilience to a major earthquake event. To accomplish this, a survey of similar organisations affected by a different type of perturbation was required to act as a comparative group.

The two major natural disaster events (perturbations) analysed in this thesis affected both farming and rural non-farming organisations and began between 4-18 September 2010 in the South Island of New Zealand. These events were the M_w 7.1 Darfield earthquake and the 2010 Southland snowstorm. Aside from occurring two weeks apart, the two events offered an unique opportunity to catalogue and analyse the impacts of two fundamentally different, but significant perturbations on both farming and non-farming organisations. The former evolved into the protracted Canterbury earthquake sequence and serves as the primary focus of this thesis, as discussed in Chapters 3-5. The latter, discussed in Chapter 6, acts as a comparison and draws on previous examples of similar snowstorm events that have occurred in both Southland as well as the Canterbury regions.

1.10 Thesis structure

Following the literature review and conceptual frameworks presented in Chapter 1, Chapter 2 describes the process and development of the methodologies and questionnaires used in Chapters 3 - 6. Following the methodological development used throughout the thesis, the immediate impacts of an earthquake event are presented in Chapter 3, which outlines the effects, responses and challenges faced by farming and rural non-farming organisations. Chapters 4 and 5 then examine the impacts of the earthquake sequence over time using both qualitative and quantitative assessments. Following the investigation of impacts of the low-frequency, high-impact event, the impacts of a relatively high-frequency, high-consequence event (the 2010 Southland snowstorm) on both farming and non-farming organisations is examined in Chapter 6. These impacts are presented afterwards to offer a comparison of a natural hazard where the impacts of the hazard threatens the base of production and uninsurable assets.

The body of the thesis is composed of four chapters, each of which contains manuscripts which have been or will be submitted to international peer-reviewed journals. Chapters 3 - 6 include brief outlines of the intended journal of publication, the manuscripts' publication status at the time of thesis submission, and the thesis objective the manuscript addresses. These four chapters address the following topics:

- Present the short-term impacts, responses and recovery strategies of farming and rural non-farming organisations to the 4 September 2010 Darfield earthquake.
- Analyse the evolution of impacts, responses and mitigating strategies of farming and rural non-farming organisations over the course of the Canterbury earthquake sequence.
- Identify and model earthquake-related geophysical metrics that are associated with organisational repair costs and disruptions.
- Present the short and medium-term impacts, responses, and recoveries of farming and rural non-farming organisations to the 18 September 2010 Southland snowstorm.

All chapters have been edited and formatted for inclusion within the thesis publication, with all references included in Section 6 following the three appendices. However, the content of manuscripts that have been accepted or submitted to journals have not been modified.

Due to thesis' wide breadth and consequent variety of foci across chapters, different theoretical frameworks are employed in Chapters 3 - 6 depending on the content matter. Chapter 3 is grounded in the engineering resilience framework, as the chapter views organisations as self contained systems, and attempts to identify factors that contribute to organisational resilience. Chapter 4 pulls back, and takes a more holistic view of the rural organisational community, which necessitates the adoption of an ecological resilience framing, but also employs the SUST vulnerability model to identify vulnerabilities inherent within the system. Chapter 5 is strongly technocratic in its attempt to model the effects of the earthquake sequence through quantitative analysis, and draws heavily from the vulnerability and DRR traditions. However, it draws on what was discovered in the preceding chapters (Chapter 3 and Chapter 4), and therefore does lean on the engineering and ecological resilience traditions. Chapter 6 is wide in scope, and draws on all traditions identified in the literature review in different sections of the chapter. In summary, Chapters 3-6 are best viewed as iterations of each other, employing different theoretical frameworks employed as means to address different perspectives of a larger story.

Appendices have been included to provide supplemental research content, including additional journal and technical report publications and survey materials. These materials support broader research aims that are indirectly relevant to the thesis material as well as provide a greater illustration of the methodological development for rural disaster impact assessment. All materials presented in this thesis have been authored by Zach Whitman. Appendices A, and B are accepted or published journal articles. Appendix C contains research materials including the questionnaires and cover letters used.

Chapter 2

Research methodology development

2.1 Overview

This thesis presents the findings from two surveys of rural organisations in post-disaster environments as a means of collecting and comparing the impact data and how it relates to the nature of the disaster as well as the organisational sector. While each of the results chapters include a discrete methods section, it is also important to first consider the broader context in which these methods are situated. This chapter presents that context and the development path of the research instruments and deployment methodologies over the course of the thesis. This includes a pilot survey that took place prior to the Darfield earthquake, from which many of the methods were developed.

The primary data for this thesis were collected through a series of questionnaires deployed in post-disaster contexts. These are supplemented with semi-structured interviews of key stakeholders. This chapter explains the development of the questionnaires used in data collection as well as their deployment methodologies. Although Chapters 3 - 6 include methods sections regarding the collection and analysis of data, this chapter provides a greater explanation of why particular methodologies were selected and how they were developed. This chapter is intended to supplement the methodology sections of Chapters 3 - 6, explain why certain methods were chosen, and what lessons were learned from the process. It is not intended for journal submission.

This chapter examines the lessons learned during the developments and deployments of the research instruments and how lessons were applied to subsequent deployments, as well as what adaptations would be helpful for future research. The results from the Hurunui survey were instructive in developing the questionnaire and deployment methodologies and therefore the results relevant to the deployment and the questionnaire development are included in the following section.

2.2 The research instruments and their deployments

There are several requisite steps in properly constraining a social survey [174]. The first steps are to (1) constrain the aims of the study, (2) review the relevant literature and (3) conceptualise the study. These preceding phases are accompanied by in-depth interviews which are designed to assist in (4) assessing the feasibility of the study, and (5) developing appropriate hypotheses. After defining and conceptualising the study, (6) the research instruments should be designed or adapted in a manner whose outputs are directly applicable to the research objectives; without clear objectives and appropriate design, these surveys can yield unusable results and waste valuable resources [174]. Following the development of the research instrument and its trial through some form of pilot study, (7) the sample frame can be established and the data collection process and analysis begin.

Following the conceptualisation, feasibility, and hypotheses development phases, a research instrument that would produce germane outputs required careful consideration. In addressing the research objectives explained in Chapter 1, a variety of variable types were required. These included basic categorical data such as owner/operator demographic information, industry sector, as well as basic quantitative data such as number of different types of employees. Ordinal variable data pertaining to the natural hazard itself were required, as were data regarding the types of impacts, disruptive influences, and the mitigating strategies employed by affected organisations. Finally, some measurements of organisational resilience and fiscal health were needed to assess whether the natural hazard had any affect on the organisations' viability and how organisational resilience was related to the organisations' experience with the hazard.

2.2.1 Research instrument design

There are different methods used in capturing organisational disaster experiences that have proven successful in New Zealand [14, 175]. For example, Smith [14] was highly successful employing the grounded theory method [176]. This method proved useful in capturing rich interview-based responses and yielded much insight into farmers' perception of disaster preparedness, governmental support expectations, and perspectives of community-based support networks. However, one fundamental weakness of this approach was that it was case-specific, and could not be readily deployed or standardized across different disaster contexts. In another post-disaster study in New Zealand, a questionnaire based survey method deployed to both farming and rural non-farming organisations following an earthquake event proved successful in gathering basic information about the responding organisations as well as impact assessments post-event [175]. The standardized assessment method was also designed to capture relatively detailed responses through the use of open-ended survey items.

Due to the wide breadth of data types, and need to compare different types of data, which included ordinal, categorical, and quantitative variables, a questionnaire based survey was selected as the best mode of collecting both quantitative and qualitative disaster impact data from a wide range of organisational sectors affected by different types of natural disasters. This is because one of the critical aspects of social survey design is the incorporation of control or comparison groups that limit the possibility of alternative interpretations of the findings [174]. A questionnaire based survey methodology also allowed for the comparison of results within a sample population and between different disaster contexts.

The definition of a questionnaire used in this study is as follows:

> 'A technique for gathering statistical information about the attributes, attitudes or actions of a population by administering standardized questions to some or all of its members.'
>
> Source: [177]

The conceptual variables used to define the questionnaires were derived from works that include Alesch et al. [4], Tierney [109], Chang and Falit-Baiamonte [111], and Rose [178], which identify the direct and indirect disruptive influences natural disasters can create for organisations. The intent of the questionnaires was therefore to systematically collect impact data through the use of Likert-scale based items [179], closed-response and open response items. The use of both closed- and open-ended items was to offer respondents the opportunity to contextualize their responses and to control for the likelihood of closed-ended items eliciting potentially forced responses [180].

Inspired by the rich responses gathered by Smith [14, 119], it was determined that semi-structured interviews would be useful for both piloting a questionnaire's usability as well as contextualizing the impacts of a natural hazard. Interviews were conducted with survey respondents, emergency management personnel, and farming support organisations, which included service providers as well as downstream clientele.

2.2.2 Item design

Item design was an important factor to consider when assessing these conceptual variables. Specifically, with regards to the type of item used in the questionnaire, there are well-understood differences between the responses elicited when using closed and open-response items [181, 182]. For example in the United States, Schuman and Presser [181] found that when respondents were asked about the greatest challenge facing the United States, those asked using a closed-form item often identified violence while those given open-form items were more likely to note political leadership challenges.

Both open- and closed-form items have the potential to create different types of biases [183]; a summary of these biases may be found in Table 2.1. For example, open-form items often suffer from high response quality variations which can make analysis difficult [184], or lead to survey fatigue due to the long amount of time required to complete the item [184]. Long surveys also can create biases for closed-form responses, specifically in the form of "no/yes saying", which is when respondents repeatedly agree or disagree to complete the questionnaire faster. Other biases specific to closed-form items include end aversion, which is when respondents avoid end-options in Likert-scale items leading to a central tendency and low variance. Also, poorly constructed closed-scale items can have issues with forced choices or missing intervals. In certain circumstances, open-ended items can be more appropriate in knowledge or attitude contexts, and can develop a

Table 2.1: Sources of questionnaire biases. Adapted from Choi [183]

Category	Source	Bias
Item design	Wording problems	Ambiguous question complex question, double-barrelled question, short question, technical jargon, uncommon word, vague
	Missing/inadequate data	Belief vs. behaviour, starting time, data degradation, insensitive measure
	Faulty scale	Forced choice, missing interval, overlapping interval, scale format
	Leading questions	Framing, leading question, mind-set
	Intrusiveness	Reporting, sensitive question
	Inconsistency	Case definition, change of scale, change of wording, diagnostic vogue
Questionnaire design	Formatting	Horizontal response format, juxtaposed scale, alignment issues
	Length	No/yes saying, open question, response fatigue
	Structure flaws	Skip logic errors
Questionnaire administration	Interviewer	Interviewer nonblinding
	Subconscious	End aversion, positive satisfaction
	Conscious	Hello-goodbye effect, obsequiousness, unacceptability, rumination
	Learning	Learning, hypothesis guessing
	Inaccuracy recall	Primacy and recency, proxy respondent, recall, telescope
	Cultural	Cultural differences

wealth of information that is appropriate for content analysis [183]. Ultimately however, the use of both closed and open-form items in concert is appropriate [184].

2.2.3 Survey iterations

Throughout the thesis, an iterative approach that repeated the steps outlined by Oppenheim [174] was adopted that refined the questionnaire and supplemented the quantitative impact items [4, 109, 111], stock and flow items [178], and recovery strategy data [111] with qualitative, open-ended items and by conducting semi-structured interviews with those directly affected by the event. Sample frames were determined by the relevance or scope of the work, and not intended to be statistically representative [176]. This iterative process is reflected in the questionnaire and deployment methodologies used in Chapters 3 - 6, with subsequent iterations taking into consideration the lessons learned from the

TABLE 2.2: Survey locations and dates of deployment.

Survey	Questionnaire	Location	Deployment Dates		Thesis Chapters
1	V1	Hurunui	June - Aug	2010	Appendix B
2	V2	Canterbury	Sep - Dec	2010	Chapter 3 & Appendix A
3	V2	Southland	May - Jun	2011	Chapter 6
4	V3	Canterbury	Apr - Jun	2012	Chapters 4 & 5
5	V3	Southland	Jul - Oct	2012	Not Included

previous data collection processes. Overall, the process produced three questionnaires and five survey deployments in three sample areas.

The development of a questionnaire that could assess organisational vulnerability and resilience to natural hazards began prior the Darfield earthquake, in the rural Hurunui district in New Zealand's South Island directly north of Canterbury. The Hurunui district had been subjected to two major flooding events (occurring in July and August 2008) as well as persistent drought conditions (beginning in 2007). The purpose of the survey was to collect data on both farming and rural non-farming organisations regarding the organisations' level of resilience and the recent experiences with natural disasters as part of a smaller, more focussed study. The lessons from the Hurunui survey formed the basis from which subsequent questionnaires would be developed. A summary of this iterative progression can be found in Table 2.2 and Figure 2.1, with the first survey iteration (V1) taking place in the Hurunui District and the later questionnaires (V2) deployed in the Canterbury and Southland districts following the 4 September 2010 Darfield earthquake and 18 September 2010 Snowstorm respectively. The last questionnaire (V3) was designed to reassess the impacts of the earthquakes and snowstorm over time and was deployed to organisations already sampled in Canterbury and Southland in 2010. Overall, the core themes of all questionnaires were the assessment of organisational impacts following the exposure to a natural hazard, the organisational vulnerability and resilience to the effects of the natural hazard, and the financial implications that followed. All surveyed organisations from each of the sample areas are shown in Figure 2.2.

To address this thesis' objectives, an important component was to develop a questionnaire that would be applicable in a variety of disaster contexts and organisational types. The basic structure of the questionnaire was to employ the resilience questionnaire defined by Lee et al. [78], and adding to that vulnerability and impact survey items drawn

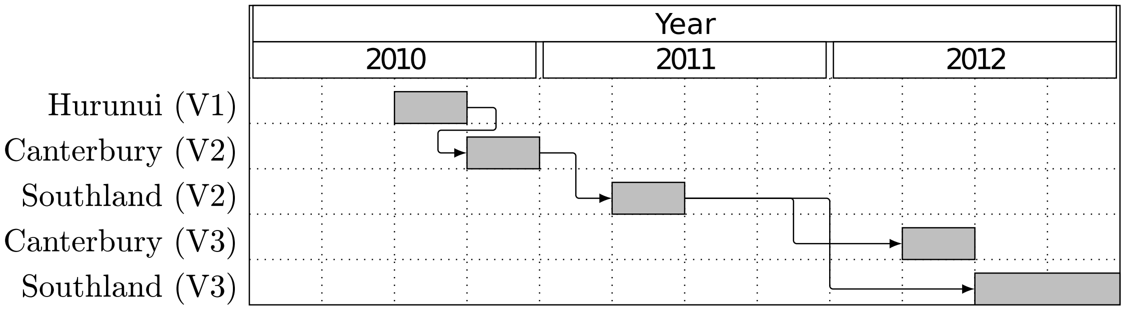


FIGURE 2.1: Simplified Gantt chart of survey deployments. The flow lines indicate how questionnaire versions V1 and V2 informed the development of V3.

from sources such as Chang and Falit-Baiamonte [111], and Tierney [109] respectively. The thesis supervisors and members of the Resilient Organisations research group were also consulted to assist in the item construction process.

From this process, the same questionnaire was able to be used to collect data immediately following the Darfield earthquake as well as the 18 September 2010 Southland snowstorm. Importantly however, the deployment methodologies used were different in the Hurunui, Canterbury and Southland samples. To clarify which questionnaire was used for each survey, all surveys conducted and the associated questionnaire versions used are listed in Table 2.2.

2.3 The Hurunui survey

The purpose of sampling organisations in the Hurunui District was to quantitatively assess the resilience of organisations in a rural setting and to gather data regarding the organisations' recent disaster experiences. This included what factors were disruptive, how the organisations mitigated the impacts of the event, what was the greatest overall challenge, and how the disaster affected the organisation's overall performance. To gather these data, a questionnaire-based approach was used.

Selection of the Hurunui District was chosen for three reasons: the incidence of a perturbation (e.g. immediate and localized flooding event) and stressor (e.g. developing and widespread drought-like conditions), the hazards having occurred within 5 years of sampling, and the presence of primary industries. Additionally, the economy is largely

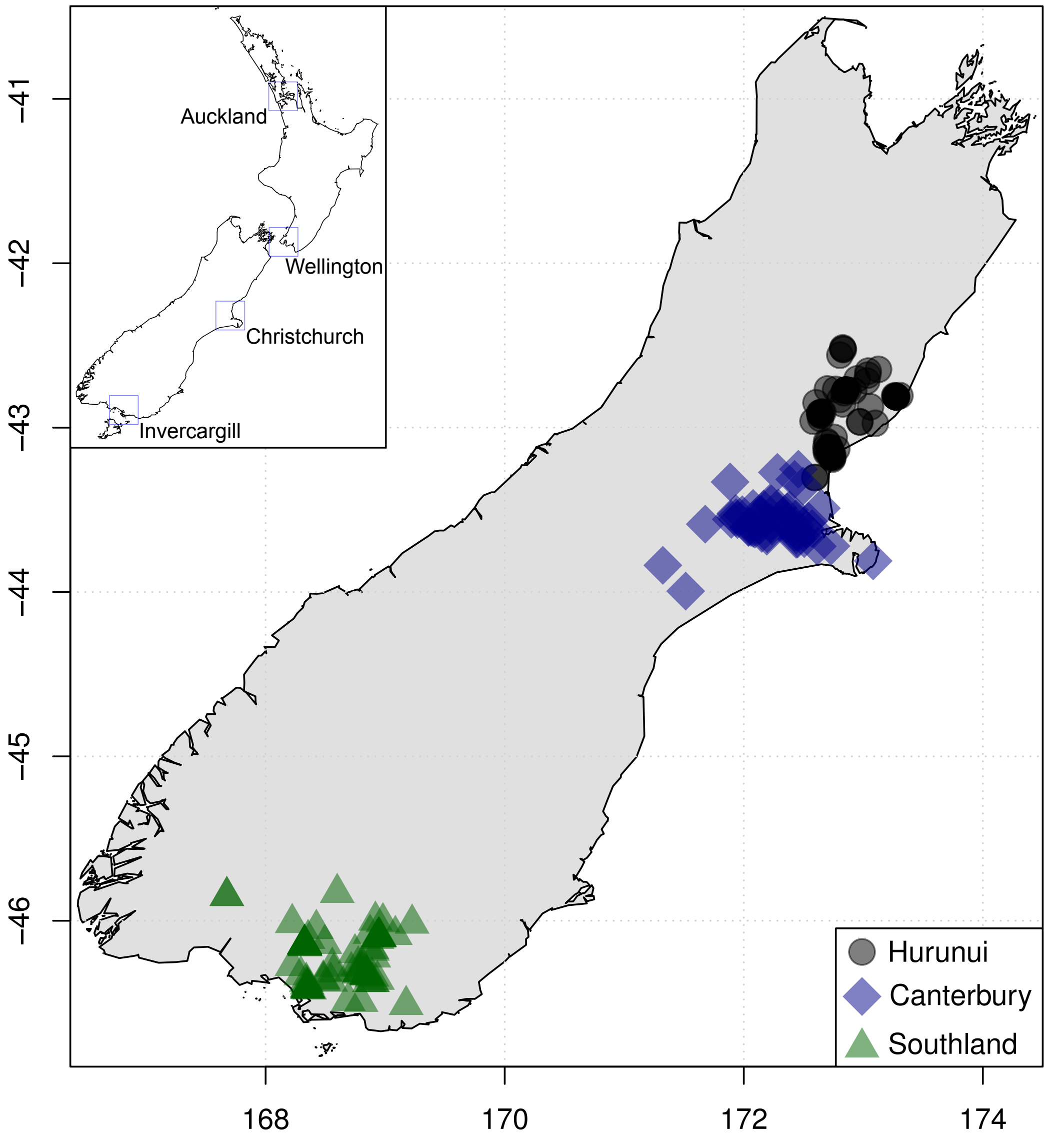


FIGURE 2.2: Map locating sample organisations.

based on the primary industries as the agricultural sectors represent nearly half (48%) of all organisations in the district [185].

2.3.1 The first questionnaire (V1)

The questionnaire was grouped into four sections. The first gathered summary demographic data about the individual participant and their organisation. The second section consisted of 53 resilience quantification scale-items as described by Stephenson [83] and

Lee et al. [78], and items regarding organisational hazard perception and planning practices. The third section catalogued the organisation's experience with disasters over the last 5 years, the levels of insurance coverage held, the recovery from the natural disasters as well as any external assistance received by the organisation for recovery purposes. The last section dealt specifically with business performance metrics such as return on investment, revenue and profitability, which was related to the Stephenson [78, 83] methodology.

The printed questionnaire included design elements such as a colour cover page and a displayed university logo as a means to attract attention and to improve response rates [186, 187]. Original formatting and item ordering for the questionnaire was adapted from the online version deployed in Stephenson [83]. An information sheet and addressed Freepost envelope were included with the questionnaire. The information sheet explained the impetus for research, and where the results will be published. Additionally, it was stated that for every response received by the research team, a donation will be made out to New Zealand Red Cross, which was again, an attempt to yield a higher response rate [188]. The complete questionnaire booklet can be found in Appendix C and the complete information sheet may be found in Appendix C. All materials were approved by the University of Canterbury Human Ethics Committee.

2.3.2 Pilot study

In accordance with the progression of social survey development [174], a pilot study was designed to gather feedback about the ease of use, length of time required to complete the questionnaire, and the perception of question applicability to small rural organisations. This was done, in part, due to the frequent use of a corporate lexicon in select questions. Organisations from the agricultural and hospitality sectors were chosen for the pilot study because these sectors are two of the most common in the district, and have averaged between 1 and 5 employees per organisation over the last 10 years [185]. All farming organisations, with the exception of one, were chosen through the emergency manager of the Hurunui District who would make contact with these farms in the event of a natural disaster to gather impact information, largely because these farms were associated with Federated Farmers. Non-farming organisations were chosen based on their proximity to areas impacted by natural disasters over the past 5 years and were solicited without introduction.

Nine organisations as well as the emergency manager of the Hurunui District were interviewed regarding their impressions of the survey. Of the nine organisations, 3 organisations were in the hospitality sectors, the remaining 6 organisations were farms, and all had experienced one or more disasters over the past 5 years. General criticisms of the questionnaire identified by a majority of the pilot study organisations were:

- Some questions were inapplicable due to the size or nature of organisation;
- Resilience quantification items become repetitive; and
- Questionnaire takes too long to complete.

In response, questions were reworded based on the comments received from the pilot study. Most of the changes made to questions consisted of simply deleting repetitive phrasing with the hopes that shortening the length of question wording while also increasing syntax variety would improve the readability of the entire questionnaire and shorten the perceived length overall. The exact phrasing changes may be found in Appendix C. The methodology of Lee et al. [78] required all organisational resilience scale-method items to accurately assess resilience and therefore no items were able to be removed.

2.3.3 Hurunui deployment

The deployment methodology used by Stephenson [83] was through an online survey engine, similar to the methods defined by Couper [189]. For the Hurunui deployment, only physical copies of the questionnaire were mailed to organisations because the farming organisations in the District often did not have readily available internet access, limited the likely response rate and biasing the results [190]. Organisations were not contacted by any other means during sampling.

Using two direct mailing services databases, 1002 organisations located within the Hurunui District were mailed the questionnaire. Questionnaires along with a colour cover

Table 2.3: Breakdown of contacted organisations and response rates in the sampled Hurunui District

Deployment	Date	Contacted	% Valid	Responses	Response Rate
1st Mailing	20-Jul-2010	1002	96	34	4%
Reminder	25-Sep-2010	930	99	37	4%
Total	15-Oct-2010	920	100	71	8%

letter shown in Appendix C and a Freepost return envelope were placed inside University of Canterbury stationary to maximize the achieved response rates [186, 187]. The general locations of these organisations may be found in Figure 2.2. The first mailing took place during July 2010. Respondents were asked to respond within 30 days. A reminder mailing was sent in late September 2010 in an attempt to increase the response [188]. The reminder notice can be found in Appendix C. As shown in Table 2.3, a second deployment, which served to remind organisations to participate was as successful as the initial deployment and doubled the response rate.

The mailed survey methodology successfully elicited responses from most sectors in the district and at relatively comparable proportions [185]. The majority (59%) of sampled organisations were from the agricultural sector. Retail trade (11%) and accommodation and food services (11%) were the most common sectors after agriculture. Several different organisational sizes reported as well, which is also consistent with the regional organisations. Over 75% of participating organisations reported having 4 full-time employees or less, and approximately 57% of the sample is comprised of organisations of 2 or fewer employees. One organisation reported having 6000 employees. Because of this, the sample distribution was strongly right-skewed with an extreme variance in the sample's number of employees. The average number of employees of 96 is significantly greater than the 5% trimmed mean of 4.

Another positive outcome of the survey was that it was not only responded to by organisations that had been recently affected by a natural disaster. Approximately half (47%) of organisations sampled had not experienced a natural disaster during the last 5 years. Furthermore, the likelihood of having experienced a disaster did not appear to be associated with only the farming organisation sectors. Although sixty percent of farms, compared to only 44% of non-farm rural organisations, had experienced a natural disaster, farming organisations were no more likely than non-farm rural organisations to report having experienced disasters, chi-square $(1, N = 79) = 1.916$, $p = 0.384$.

It was also clear that the questionnaire items were capable of collecting valuable data regarding a variety of different types of perturbations or stressors. The most common threat perceived by sampled organisations was from natural disasters, followed by financial crisis. The third most-common fears were major accident or fire, and the failure of key customers or suppliers. The survey data also demonstrated that the farming organisations were more concerned with the threat of natural disasters than the rural non-farming sample group. Of the 78 organisations that chose to respond to the question, 46% ($N = 36$) indicated that natural disasters was the primary threat to the organisation, while 54% indicated other threats as the primary concern for the organisation. Sixty-two percent of farms ($N = 28$) and 24% of non-farm organisations ($N = 8$) indicated that natural disasters were the primary concern. Farming organisations were significantly more likely than non-farm rural organisations to report natural disasters as a primary concern to the organisation, chi-square $(1, N = 78) = 11.05$, $p = 0.0009$.

Quantitative disaster impact items were successful in assessing organisation's greatest perceived threats, recent disaster experiences, the severity of the event, and whether insurance claims were filed in response. These disaster-related quantitative items showed low rates of omission from both farming and rural non-farming organisations while providing useful data that were suited for statistical analyses. However the Hurunui questionnaire had very few of these items and therefore expanding this section was identified as an area of opportunity.

One experimental item design, shown in Figure 2.3, proved successful in quickly assessing organisational performance over six years using a 5-point Likert scale item. The item was designed to allow for rapid responses, generalized approximations, and low cognitive overhead. Instead of asking organisations to rate the organisation's performance every year, the respondent was instructed to plot a single line that represented organisational performance over time.

Open-ended qualitative items provided detailed descriptions of organisation's disaster experience and impact, often including detailed cost and downtime estimations, as well as psychosocial impacts. These items allowed respondents the opportunity to report impacts that were not addressed in quantitative closed-response items. Additionally, once coded these qualitative results could be used to analyse for impact patterns.

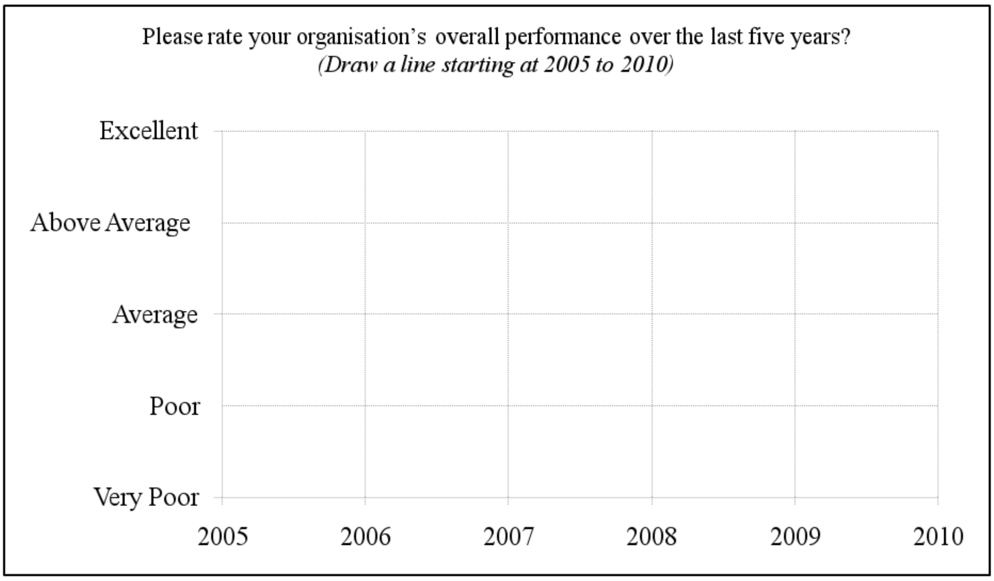


FIGURE 2.3: Experimental design of a multi-year Likert-scale assessment of organisational performance.

2.3.4 Areas for improvement

One evident short-coming of the survey design was the frequency of item-omissions in questionnaire responses. Respondents were not required to complete every question in order to complete the questionnaire, and consequently a significant number of missing values existed in the dataset. The majority of non-responses were clustered within the resilience items which comprised the majority of the first portion of the questionnaire.

The Hurunui questionnaire included a section of 53 items that, when completed in total, were capable of assessing the organisation's level of resilience [78]. These items, termed "resilience questions", were however very likely to be omitted by respondents. Of the 80 sampled organisations, only 61% ($N = 49$) completed all resilience questions while approximately 23% ($N = 18$), chose to omit 2 or more. The large majority of sampled organisations completed 95% of the resilience questions, but there were some that chose to omit over 40% of resilience questions. Of those who chose to omit questions, 35% noted the reason to be that the question was inapplicable, identified by participants writing the answer N/A in the margins of the questionnaire.

The resilience items appeared to induce survey fatigue for sampled organisations, with organisations proving more likely to omit items as they completed additional resilience items. A significant positive correlation was found between the number of resilience questions answered and the number of organisations choosing to omit items ($r = 0.758$, $p = .001$). As shown in Figure 2.4, the correlation is more pronounced for farming organisations ($r = 0.822$, $p = .000$) than for non-farming industries ($r = 0.433$, $p = .001$). The size of the organisation showed no significant correlation with the number of omitted resilience questions ($r = -0.063$, $p = 0.581$).

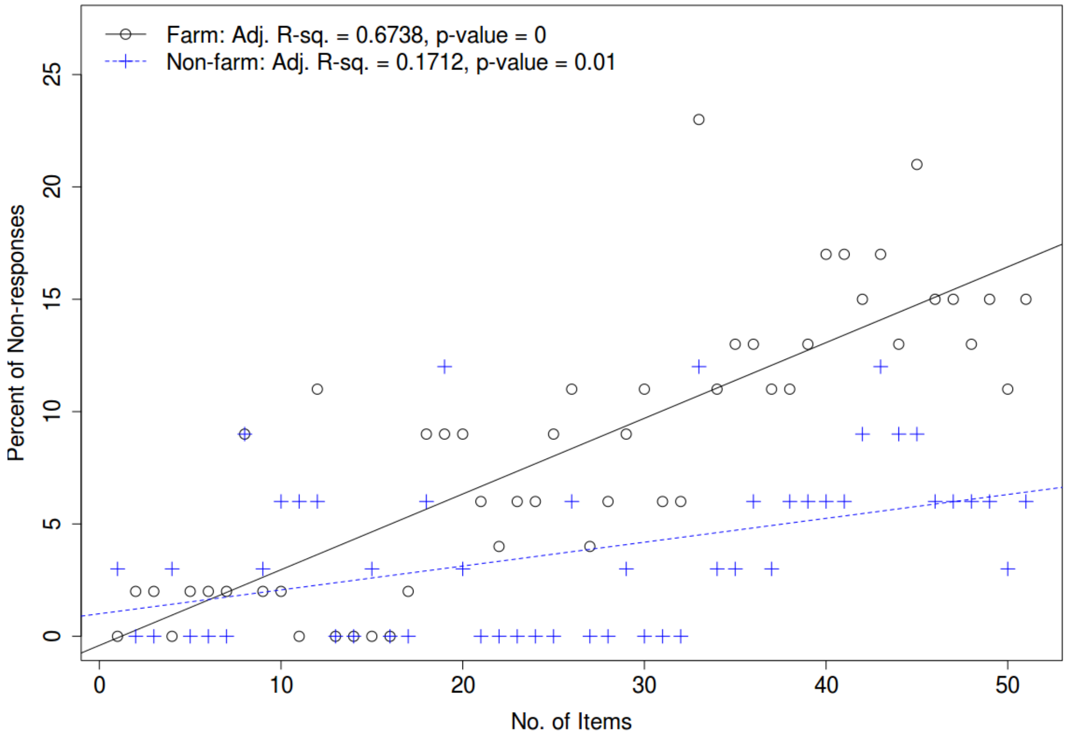


FIGURE 2.4: Illustration of the increasing frequency of organisations to omit resilience questions. The x-axis is the number of resilience questions completed by the responding organisations and the y-axis is the percentage of respondents omitting each item. As the organisations complete more items, the more likely they are to omit subsequent resilience questions. Farming organisations show a more consistent pattern of omission to that of non-farming organisations. "No. of items" is the number of resilience items."

Twenty-three organisations omitted one or more resilience questions while 8 took the time to indicate one or more questions were not applicable by hand-writing N/A in the margins of the questionnaire. The average number of omissions for those who skipped resilience questions was 5.96 ($StDev = 8.80$) and 15.63 ($StDev = 9.15$) for those who indicated questions were not applicable. The 95 per cent confidence intervals for the means are 4.16 to 18.48 for those who skipped and 15.17 to 44.23 for those who indicated the question was not applicable; there was a significant difference between the number of resilience questions skipped by those who indicated the question was inapplicable when compared to those who did not $t(29) = -2.65$, $p = 0.013$ (2-tailed). Therefore, organisations that found questions to be inapplicable were more likely to omit these resilience questions, increasing the non-response bias within the sample and highlighting opportunities to retool indicator questions to better suit the widest potential sample range.

Chi-square was used to examine whether a farming organisations was responsible for reporting questions as 'not applicable' (N/A). While 7 out of the 8 organisations that reported questions to be 'N/A' were farms, the difference between these two groups was not statistically significant, chi-square $(1, N = 80) = 3.03$, $p = 0.082$ (2-tailed). This result requires further investigation to make a definite claim as to whether item inapplicability was sectorally related.

2.3.5 Lessons for the subsequent surveys

The Hurunui deployment was a valuable exercise in survey development. From the results, the lessons learned were:

1. Disaster experiences can be collected through generalized surveys and is in agreement with previous disaster research [4, 109, 111, 173].
2. Item omissions must be decreased substantially, either through shorter form questionnaires [183, 191], or improved content applicability [192].
3. Multi-media deployment methods will likely improve response rates [193, 194].

Both farming and non-farming organisations showed a willingness to participate in the study and organisational size was not a predictor for participation. Furthermore, the survey collected data from organisations with and without recent experience with natural disasters. Survey items were also able to define what hazard was perceived to be of greatest threat to the organisation, and open ended questions successfully collected detailed and highly useful data [180], specifically regarding disaster impact. However, the use of quantitative methods to collect impact data could have been expanded to better catalogue the impacts and recovery strategies employed during the event.

Farms exhibited significant survey fatigue, and were less likely to complete as many resilience questions as the rural non-farm organisations. Although the survey length was noted by organisations in the pilot study to be a negative feature, it is plausible that those organisations did not omit items because of the researcher's presence while these organisations completed the questionnaire. The rate at which organisations would omit items was an unconstrained factor biased by the interview-based format of the pilot study.

While item-omissions did occur in other sections, the most frequently omitted items in the questionnaire were items associated with the Lee et al. [78] model. The number of resilience items included in the model by Lee et al. [78] was found to be the major cause of survey fatigue for both farming and non-farming organisations. Additionally, work was required to confirm the applicability of all questions and for items to include a 'N/A' answer option on future questionnaires, which would provide respondents a mechanism to easily identify or report the rationale for skipping a question.

As long-form questionnaires have been shown in the past to elicit lower response rates [191], these findings prompted the development of a short-form version of the scale assessment methodology that would allow for a statistically valid assessment of organisational resilience to be included alongside natural hazard impact questions without inducing survey fatigue. A detailed explanation of the short-form method development may be found in Appendix B.

Finally, it was clear that using a mailed questionnaire would continue to produce low response rates, and alternative data deployment and collection methods should be considered. Online distribution methods are not ideal as many of the organisations may not typically access a computer on a daily basis and therefore simply reproducing the methodology designed by Lee et al. [78] was untenable. In prior research the Ministry of Primary Industries (formally the Ministry of Agriculture and Forestry) collected survey responses through phone interviews [195]. Consequently, multi-media deployment utilizing the Dillman [192] method was identified as an improved deployment methodology.

These lessons learned from the Hurunui survey were applied to the surveys conducted immediately following the 4 September Darfield earthquake in Canterbury and the 2010 Southland snowstorm. The Canterbury deployment preceded the Southland deployment and although the same questionnaire was used for both deployments, some of the lessons learned in the Canterbury deployment were applied to the sample selection and deployment method for the Southland sample.

2.4 The second questionnaire (V2)

Following the conclusion of data collection for the first questionnaire (V1) in the Hurunui district, two major perturbations occurred within weeks of one another in the South Island of New Zealand. Both the 2010 Darfield earthquake and Southland snowstorm affected rural organisations at approximately the same time in very distinct manners, providing a relatively well-controlled natural experiment of the effects of different perturbations on rural organisations in New Zealand. These events acted as the catalyst for the further development of the first questionnaire into what would become the second questionnaire (V2) as the scope of the thesis quickly expanded to include these two events. Ultimately following the events, the conceptualization of the thesis was finalized and a third questionnaire was planned for deployment approximately 1.5 years afterwards as a follow-up study .

The second questionnaire was deployed immediately following the Darfield earthquake and Southland snowstorm in 2010, the results of which can be found in Chapters 6 and 3, as well as Appendix A. The main objectives of the questionnaire were to identify the disruptive factors of the event, the factors that proved helpful in mitigating the effects of the event, and to quantitatively assess the resilience of the organisation using a short-form version of the Lee et al. [78] Organisational Resilience model.

The overall motivation for the second questionnaire was to provide a rapid assessment of the impacts and resilient capacity of rural organisations following an earthquake event. These results were intended to assist in the rapid identification of the worst-affected areas and allow relief organisations to prioritize or concentrate their efforts on those areas most affected. These aims aligned with the interests of the Ministry of Primary Industries, the GNS RiskScape project, and Resilient Organisations, and as a consequence representatives from these groups were either consulted or active participants during the questionnaire development process.

2.4.1 V2 questionnaire development

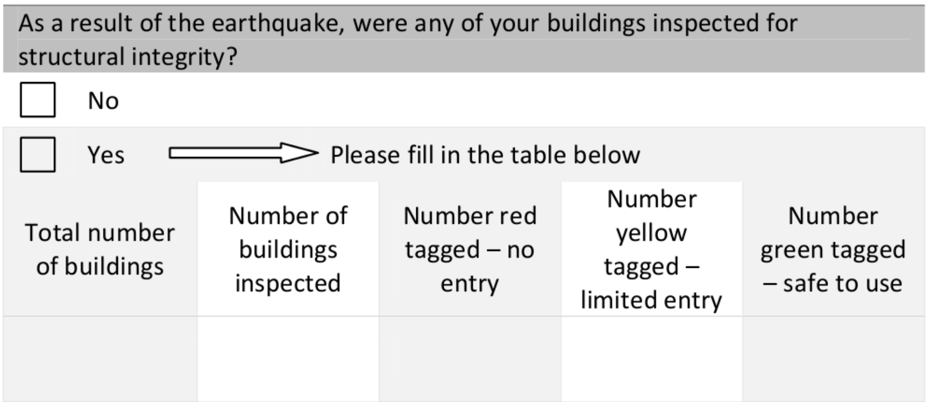
From the lessons learned in the Hurunui questionnaire (V1), two specific objectives drove the majority of changes found between V1 and V2. These include:

1. Create quantitative items that capture the impact of the event and the factors helpful in mitigating the effects.
2. Create a short-form version of the resilience quantification method developed by Lee et al. [78], which would decrease the number of resilience items from 53 to 13.

One lesson learned from the Hurunui deployment was that there was an opportunity to expand the number of quantitative impact assessment items. Therefore the questionnaire included an adaptation of the method developed by Chang and Falit-Baiamonte [111] to quantify disruptive elements and potential mitigating factors through the use of a Likert-scale rating. The results produced by this item were very useful in identifying the most common disruptive elements as well as the most severe, while also applicable in cataloguing factors found helpful in mitigating the effects of the event. A detailed explanation of this item and its implementation can be found in Chapter 3.

In certain circumstances quantitative items proved less successful, and consequently quantitative item design was an area that was identified for improvement. While the majority of these items proved successful, there were a few select examples similar to the example shown in Figure 2.5, where items that were designed to capture multiple attributes in an attempt to decrease survey fatigue ultimately created muddled results that were not suitable for analysis. The item was designed to collect the damage state of the organisation's building and yielded poor results for the following three reasons:

1. Not all buildings, most especially for rural organisations, had been inspected.
2. In several circumstances, buildings received multiple inspections which produced different tags and the item did not account for these changes.
3. The item does not collect the building's purpose which is critical in understanding the disruptive influence of the damage on the organisation.



As a result of the earthquake, were any of your buildings inspected for structural integrity?

☐ No

☐ Yes ⟹ Please fill in the table below

Total number of buildings	Number of buildings inspected	Number red tagged – no entry	Number yellow tagged – limited entry	Number green tagged – safe to use

Figure 2.5: Poorly constructed structural damage assessment item.

Open ended items were again utilized in the Canterbury survey and were very useful in contextualizing the responses to the greatest challenges and mitigating factors items. Once coded, these items were also very useful in identifying potential issues that were not explicitly addressed in closed-answer items. The psychosocial impacts of the event were most readily captured using these open-ended response items and consequently better informed the results of the study.

Item omission rates dropped significantly in the second questionnaire. This was likely due to the use of a short-form version of Lee et al. [78] organisational resilience quantification methodology. The short-form version also included the option for organisations to report items as being not applicable which assisted in further developing the model.

2.4.2 The Canterbury deployment

The Canterbury sample consisted of organisations located in a rural area west of Christchurch that had been subjected to the Darfield earthquake, which is explained further in Chapter 3. Conducted between September and December 2010, the survey consisted of two questionnaires that were designed to capture organisational impact, response and recovery data.

Two sampling methodologies were used for the Canterbury deployment because a rapid online deployment to farming organisations was available immediately following the

Darfield earthquake and a subsequent multi-sectoral collaborative opportunity was available in the months following. The questionnaire distributed only to farming organisations was deployed using a farm-specific governmental support website, and was informally labelled the 'farm-specific questionnaire' (FSQ). The subsequent questionnaire was developed for use in a multi-sectoral study and was informally labelled the 'resilience questionnaire' because of the inclusion of the short-form version of the resilience quantification methodology – as described in Appendix B – originally developed by Lee et al. [78].

The 'resilience questionnaire' (RQ) utilised the majority of items that were used in the FSQ, and the questionnaires were designed to be directly comparable. Specifically, the core suite of impact and mitigating strategy questions were largely identical between both questionnaires and thus compatible. Some items in the 'farm-specific questionnaire' (FSQ) required minor diction changes that would improve the item's applicability to a broader range of industry sectors.

The major difference in content between the two questionnaires was that the FSQ included items related to the perceived shaking directions, patterns of ground deformation, and changes in the water table observed on farm. Another major difference between the two questionnaires was that they were deployed differently. The FSQ was deployed online while the questionnaire deployed to both farming and non-farming organisations was distributed to every organisation along five 25km long transects running perpendicular to the fault surface expression, crossing intensive farmland as well as farm support towns. The FSQ was also deployed first, going live by the end of September 2010. The multi-sectoral questionnaire was not deployed until mid-November.

The use of two questionnaires and deployment methodologies proved helpful in increasing the overall sample size and analytical power. However, the logistics of operating two deployments of similar surveys in parallel proved to add unnecessary complexity and ultimately a singular deployment was viewed as a preferred method for future surveys.

2.4.3 Adaptations and challenges

The most prominent lesson adopted from the Hurunui was in the deployment methodology used for the RQ in contacting both farming and rural non-farming organisations.

While sample organisations were still delivered a hard-copy to their physical address, the Dillman [192] methodology was employed and organisations were contacted by telephone in cases where a phone number could be matched to the physical address using the telephone directory. When contacted, organisations were offered additional media formats with which they could participate, including conducting the questionnaire over the phone at that time or at a later scheduled date, or through an online survey engine. As a result, the response rate for all rural organisations was 24%, which is more than double the response rate attained following the Hurunui survey. Broken down by sample group, the response rate for farming and rural non-farming organisations were 21% and 27% respectively.

The major problem with the hand-delivering deployment methodology was that it was not possible to find phone numbers for all addresses, and farming organisations that were not called exhibited a much lower rate of return. Only one third (31%) of farming organisational addresses were able to be found in the telephone book and consequently the response rate for farming organisations in total was 21%. However, the response rate for farming organisations with a valid telephone number and were called was 47%. Telephone numbers for rural non-farming organisations in the vast majority of cases were easily located in the phone book. Consequently, it was clear that collecting telephone numbers for the sample area can have a very positive impact on the response rates.

The farm-specific questionnaire (FSQ) that was only hosted online through the farm-specific, governmental support website collected very useful data and expanded the farming sample size. However, deploying online made it impossible to calculate a response rate and offered no control in sample selection. Ultimately while the data collected proved to be positive for the survey results, it was decided that future deployments should be unified to avoid minor discrepancies between survey items and to better control sample selection. The online survey deployment also introduced a potential self-selection bias that was not present in the RQ as organisations were not solicited to participate, but had to have the initiative to visit the farm-support and information distribution website. The use of an online survey also has the bias of preferencing respondents that are comfortable with using the internet.

2.4.4 The Southland deployment

The Southland deployment took place in late May which was approximately 5 months after the Canterbury deployment, and was designed to use the same questionnaire used in the RQ deployment in Canterbury, but with an improved deployment methodology. As shown in Chapter 6, several changes in the deployment methodology were established due to the challenges experienced during the Canterbury deployment, both in terms of the difficulty in locating valid phone numbers and using an online as well as hand-delivered distribution system. The Southland deployment was redesigned to ensure that all organisations that received a questionnaire were also reachable by telephone. Additionally, unlike the earthquake which had produced a fault scarp, the snowstorm lacked a distinguishing feature to sample across using transects and therefore organisations were randomly sampled using geographically defined sample frames.

The sample area was divided into 13 sample frames, and organisations were randomly selected from within each frame. A public directory of regional farming organisations in the area was used to collect a listing of farming organisations' addresses and telephone numbers. The farm location map divided the region into 25km by 17.5km reference grids and provided farm addresses, contact information, as well as a reference grid location. The reference grids were used to sub-divide the sample frame for the sample methodology. All farms listed in the farm address book were separated into tables according to the corresponding grid reference number. Then within each grid reference list, farms were ranked by randomly assigned values through the use of random number generator, and selected based on these values.

Rural non-farming organisations were selected using what may be defined as a cluster sampling technique [196], with organisations sampled from five rural townships. Organisations in each of the townships listed in the telephone book were collected and randomly assigned values through a structured table with a random number generator applied to each row. The table was then sorted by these random values. To account for differences in the township sizes, 100 organisations were randomly selected from the city of Invercargill, and 50 organisations from each of the smaller townships. In total, 300 farming organisations and 300 rural non-farming organisations were contacted.

Organisations were contacted in the exact same manner employed in the Canterbury sample, employing the methodology defined by Dillman [192]. The timing of sampling was notably later than in Canterbury, as organisations were first contacted in late May (8 months following the event) and were given 5 weeks to respond to the questionnaire.

The response rate achieved for farming organisations was 10% and 18% for non-farming organisations. These results are lower than expected based on the result of the Canterbury sample set that were reached by phone. The low response rate may be due to the different sample location, the nature of the event itself, or because the questionnaire was deployed much later when compared to the Canterbury sample.

2.5 The third questionnaire (V3)

The purpose of the third questionnaire (V3) was to follow up with respondents who participated in the second questionnaire and reassess how the impacts of the event were perceived, what were the persistent challenges over time and what strategies were being used to mitigate those challenges. The 'follow-up questionnaire' also provided the opportunity to assess the financial impact of the event, and what if any medium term changes or adaptations had taken place since the initial event.

The third or "follow-up" questionnaire took place in June of 2012 – approximately one and a half years following the previous data collection – and was only distributed to organisations that had taken part in prior research in Canterbury or Southland. It was designed to be comparable to the results of the previous questionnaire, while also making improvements to item design so that results may be better utilized in subsequent analysis. The results from the third questionnaire deployment in the Canterbury region may be found in Chapters 4 and 5. The questionnaire itself may be found in Appendix C.

2.5.1 V3 development

The development of the V3 "follow-up questionnaire" incorporated the lessons from the V1 and V2 questionnaires, and ultimately proved the most successful. The major changes made between V2 and V3 were:

1. Refine and expand use of open-ended items as a means to both assess the nature of the event and understand the use of social networks post-event.

2. Further quantify impacts of the event through methods developed by the RiskScape program.

The number of open-ended items was increased in response to their success in collecting nuanced and useful data in the Hurunui, Canterbury, and Southland surveys. Unlike the questionnaires used in the first deployments in Canterbury and Southland but similar to the method used in the Hurunui questionnaire, organisations were asked to qualitatively describe the impacts in their own words prior to answering any other impact questions. This was done because of the proven efficacy of the open-ended items in gathering rich, contextualized impact data. Some additional open-ended items were in the form of a name-generator [197], which is a method of using an open-ended item to collect the unprompted responses of the organisation. The item is then followed by a series of prompted open-ended items that specifically collects data regarding potential responses that may have not been included in the unprompted item. In the questionnaire, this took the form of first asking organisations to list individuals or organisations that were helpful in mitigating the effects of the event, and then using prompts to elicit responses for likely individuals or organisations. This allowed for the respondent to specifically describe their support network in both a prompted and unprompted setting.

The method of assessing organisational damage states was further refined to better understand the organisational asset damage state, as shown in Figure 2.6. Additionally, respondents were prompted to include specific dollar losses in the form of repair costs of structural damage, non-structural damage, clean-up and disruption costs. The item used to collect these data may be found in Figure 2.7. These items, employed in concert with the adapted methodology of Chang and Falit-Baiamonte [111] developed in the previous questionnaire, were helpful in contrasting the disruptive factors with the factors that proved most costly for the organisation to restore.

Another item that was included from the Hurunui questionnaire was the time-series Likert-scale rating of organisational performance similar to Figure 2.3. As shown in Figure 2.8, the item design was also adapted to gather percentage revenue changes over time. Due to the complexity of the question, an example item was also provided. Ultimately, the item showed low omission rates, and proved successful in gathering revenue change estimates over time.

Please indicate the type of damage that was observed to buildings on-site that are of high importance to the organisation's ability to operate. *(If the damage to high-importance buildings was variable, please explain in additional sheets).*					
Damage Description	**4 September 2010**	**22 February 2011**	**13 June 2011**	**23 December 2011**	**Other – Date (DD/MM/YY)**
No damage, or minor non-structural damage	☐	☐	☐	☐	☐
Non-structural damage only	☐	☐	☐	☐	☐
Reparable structural damage	☐	☐	☐	☐	☐
Irreparable structural damage	☐	☐	☐	☐	☐
Structural integrity fails	☐	☐	☐	☐	☐

FIGURE 2.6: Improved structural damage assessment item.

Please estimate the total/overall value of your holdings:	**$**

Please estimate the reinstatement costs for the following items as well as the value of the holdings for each category:						
		4 September 2010	**22 February 2011**	**13 June 2011**	**23 December 2011**	**Other – Date (DD/MM/YY)**
Damage	**Description**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**	**Cost ($)**
Asset Repair	Costs incurred in restoring/repairing/replacing assets (Buildings, Silos, Livestock, Vehicles and other machinery, etc.) to their pre-event state					
Contents Repair	Costs incurred in returning the contents (if any) of the asset to their pre-exposure state					
Clean-up	Costs incurred for necessary demolition, and/or removing debris, silt, effluent etc.					
Disruption	Costs incurred due to the disruption of activities usually conducted					

FIGURE 2.7: Repair cost estimation item.

Only organisations that participated in the initial questionnaire and that had agreed to take part in future research were contacted in the "follow-up" deployments for both the Canterbury and Southland. Organisations that did not respond to the initial questionniare or stated that they were not willing to participate in future research were not contacted. The Canterbury and Southland samples were contacted using the same process with the exception that data collection occurred at different times of the year. Organisations were again sampled using the Tailored design Dillman mixed-mode method [192–194].

The Canterbury sample organisations were most comfortable participating over the phone or using the online survey engine, and were very willing to participate. As a result, a response rate of 71% and 70% for farming and rural non-farming organisations respectively. In contrast, the Southland sample organisations preferred having the questionnaire mailed to them and took much longer to respond. The resulting response rate

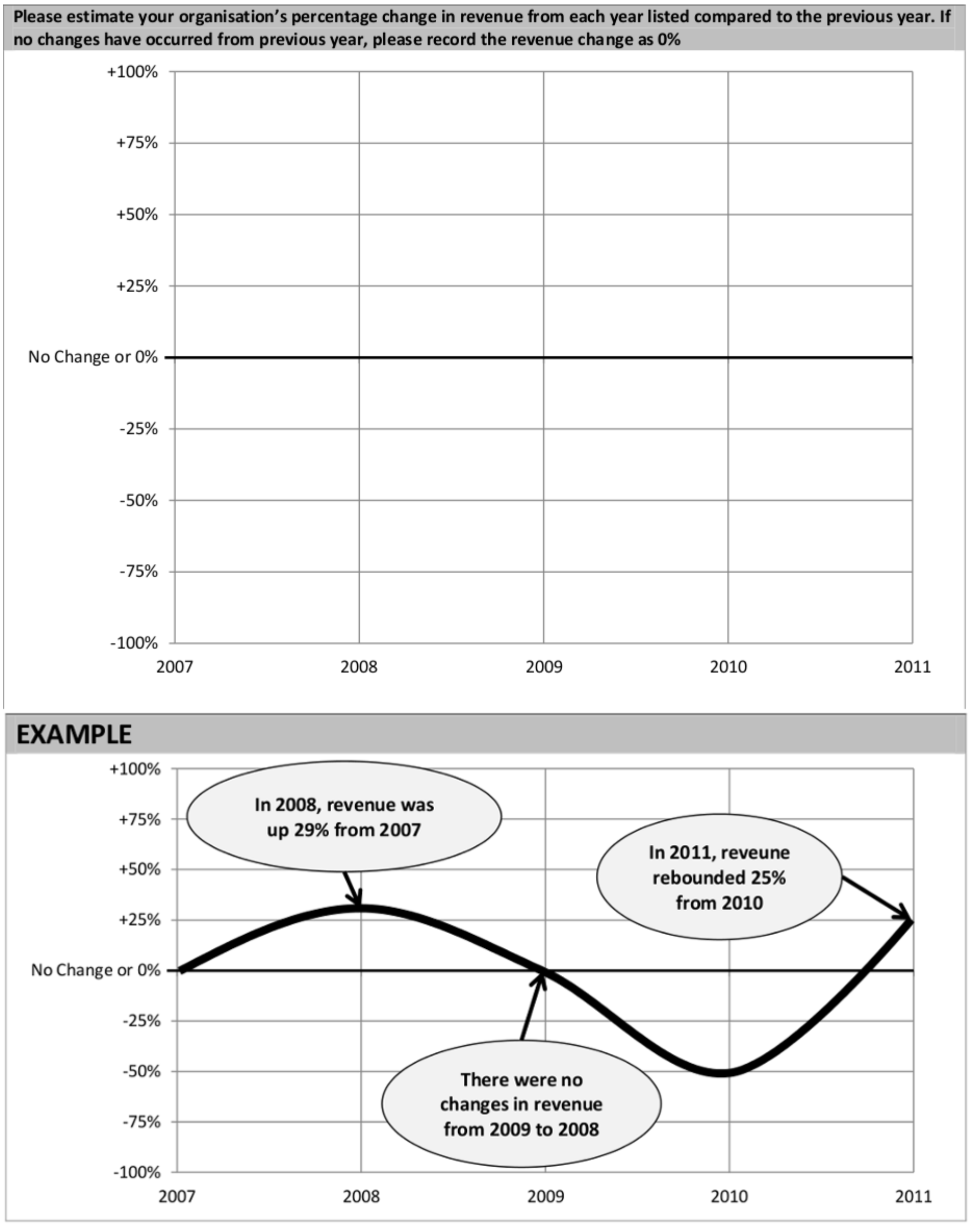


Figure 2.8: Item design to gather organisational revenue change estimates over time.

was again, lower than Canterbury. Overall, 29% of farming organisations and 25% of non-farming organisations participated from the Southland sample.

2.6 Summary

The purpose of this chapter was to explain the development of the methods used throughout the thesis, specifically addressing the iterative approach of refining the questionnaire development and deployment methodologies. Overall, the first questionnaire developed for use in the Hurunui district (V1) was adapted, refined, and re-purposed into the second version (V2) for use following both the Darfield earthquake and Southland snowstorm. The third questionnaire (V3) was again, a refined and re-purposed version of V2, ultimately proving most successful in terms of data quality and usable outputs.

In general, the process has led to three conclusions:

1. The deployment methodology used in the first Southland distribution was most effective as a first point of contact scenario.

2. The V3 questionnaire captured most usable quantitative and qualitative data by employing adapted versions of Chang and Falit-Baiamonte [111], and Bailey and Marsden [197].

3. The short-form version (as explained in Appendix B) of Lee et al. [78] drastically reduced item omission while maintaining for robust impact and resilience assessments.

The deployment methodology employed in the first Southland distribution was the most effective in selecting a wide ranging sample set that was sensitive to organisational cluster densities. Farms were able to be contacted as phone numbers were sourced prior to deployment and sample coverage of the area was ensured through the use of geographically defined sample frames which established a distributed random selection process.

Overall, the third or "follow-up" questionnaire proved to be the most successful in terms of producing data most suited for robust analysis. As illustrated in Chapters 4 and 5, open-ended qualitative items elicited a different type of response when compared to more quantitative assessments and the combined use of both types of responses likely produces a more comprehensive assessment of organisational impact following the event.

The development of the short-form version of the Lee et al. [78] model significantly decreased survey fatigue and was able to be used in concert with lengthy disaster-impact items. Ultimately, a complete assessment of organisational resilience would require the use of the original model developed by Lee et al. [78]. However in a post-disaster setting, the short-form version is most suitable as it allows for a rapid assessment and can be used alongside disaster-related impact items.

For future studies, the "follow-up" questionnaire as detailed in Chapters 4 and 5 would yield the most usable results that would collect financial health data as well as personnel and social network data. The questionnaire should be distributed in a manner appropriate to the nature of impacts caused by the natural hazard and organisations should be contacted using the Dillman [192] method, as the several different attempts to increase mailed questionnaire response rates had little measurable effect in comparison. To collect organisational resilience data, it is recommended that the short-form version of Lee et al. [78] be deployed first to allow for a rapid assessment and the full model be deployed at a later time.

Chapter 3

Rural organisational impacts, mitigation strategies, and resilience to the 2010 Darfield earthquake, New Zealand

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3.1 Overview

This chapter serves as a first-order analysis of the short-term impacts of a major earthquake event on farming and rural non-farming organisations. The results presented identify the disruptive elements for both types of organisations, the factors helpful in mitigating the effects of the event, as well as the greatest challenges. This chapter is intended to be used to assist in developing further earthquake impact studies on rural organisations through the documentation of empirical evidence.

The theoretical framing in this chapter is largely grounded in engineering resilience theory, viewing organisations as individual systems wherein which single states of stability exist, with ephemeral or transient system states can exist during a stressor or perturbance. Therefore the mention of resilience is attributable to the engineering resilience definition. In determining factors affecting systemic (organisational) resilience, quantitative vulnerability assessments are employed similar to those of Alesch [4], who also derive theoretical grounding from engineering resilience.

3.2 Contributions

Supervised by Dr. Wilson, Dr. Seville, and Dr. Vargo, Mr. Whitman worked in collaboration with Mrs. Stevenson and Ms. Kachali to develop the questionnaire used for data collection. The sample selection and distribution methodology was developed by Mr. Whitman and Dr. Wilson. Mr. Whitman distributed the questionnaires, contacted responding organisations with the assistance of research assistants, and analysed the resulting data. Lastly, all authors took part in providing comments and revisions to the manuscript.

3.3 Abstract

The 4 September 2010 M_w 7.1 'Darfield' earthquake and associated aftershock sequence affected the central Canterbury Plains of New Zealand's South Island, an area of high-intensity agricultural production located west of Christchurch, supported by rural service towns. With rural organisations exposed to intense ground shaking that caused

widespread critical service outages, structural and non-structural damage to built infrastructure, as well as ground surface damage from flooding, liquefaction or surface rupture, the event represented a unique opportunity to study the impacts of a major earthquake and aftershock sequence on farming and rural non-farming organisations. This chapter analyses the short-term impacts to 56 farming organisations and compares them to the impacts to 22 rural non-farming organisations four months following the event. The most commonly cited direct impacts to farming organisations were disruption to electrical services, water supply disruption and structural damage. For rural non-farming organisations, the most common direct impacts were non-structural damage, electricity disruption, and damage to equipment. The effect of stress on farmers was the greatest organisational challenge while rural non-farming organisations cited maintaining cash flow to be of greater significance. In terms of mitigating the effects of the event, farming organisations cited well-built buildings and insurers to be helpful generally, and their neighbours to be most helpful specifically in areas of higher intensity shaking. Rural non-farming organisations utilised lenders or insurers, and showed very little use of neighbour relationships. In summary, this study emphasizes the fact that farming and rural non-farming organisations are impacted and respond to an earthquake in ways that are fundamentally distinct.

3.4 Introduction

On 4 September, 2010, the M_w 7.1 Darfield earthquake caused widespread damage throughout the central Canterbury plains of New Zealand, a region populated by high-intensity farming organisations and rural support towns. The earthquake produced a 30 km long surface rupture through intensive farmland and caused localized flooding, extensive liquefaction most notably in Christchurch city, and peak ground acceleration (PGA) values that exceeded 1g close to the fault rupture [198, 199]. Shaking intensities and durations varied significantly by location due to differing soil densities as well as other factors [200]. In many locations proximal to the fault trace as well as in Christchurch city, design spectra for a 500-year return interval and New Zealand building codes were exceeded for several seconds [201, 202]. The earthquake was felt across New Zealand and the perceived intensity of shaking was documented by the 7,000 felt reports submitted using the GeoNet website [203].

Immediately following the event, electricity services were disrupted for more than 166,000 customers across central Canterbury [201] and reticulated water and waste-water services for both network and individual systems were disrupted for several days for many rural areas. Preliminary economic loss estimates for the event reached $4 billion NZD ($3.8 billion USD), with approximately $1 billion NZD ($0.8 billion USD) attributable to commercial damage [204]. Over a period of four months following the event, the region was subjected to over 1000 aftershocks of M_w 3.0 or greater, the majority of which were very shallow causing localized, high intensity shaking near the ground-surface rupture features of the Darfield earthquake [205].

Reports from rural areas indicated the earthquake and aftershock sequence caused a wide range of impacts on rural organisations and communities [206, 207]. These included damage to rural organisational infrastructure as well as psychosocial trauma and elevated stress levels [207].

While the effects of earthquakes to the physical and social environments are well documented across a range of magnitudes, countries and socio-cultural contexts, there are no studies in the international disaster literature that analyse the impacts of a major earthquake on farming or rural non-farming organisations in developed nations. The overall objective of this study is to document the short-term impacts of the Darfield earthquake on rural organisations so as to assist in the prediction of likely effects for future events and to inform ways to enhance resilience. Documenting these effects is needed, especially in New Zealand which is seismically active and where farming organisations are major contributors to the local and national economies [208]. Further, it is important to constrain the types of impacts to rural organisations as the sustainability and health of rural communities are associated with the health of local organisations [14]. Considering the potential effects to New Zealand's national and local economies, as well to rural community sustainability, the Darfield earthquake is an unprecedented opportunity to document the rural organisational impacts, recovery strategies, and greatest challenges faced in the aftermath of a major earthquake and aftershock sequence.

For the purposes of this study, rural organisations are divided into two generalized groups: farming and rural non-farming organisations. Organisations under the agricultural classification under the ANZSIC 2006 convention [209] were defined as farming organisations while all remaining subsectors were defined as rural non-farming organisations. The impacts experienced by these two groups are catalogued with the objective of answering four questions: (1) what effects did the earthquake have on farming and rural non-farming organisations? (2) were farming organisations affected differently than rural non-farming organisations? (3) what were the factors that proved most helpful in mitigating the effects for both farming and rural non-farming organisations? and (4) which readily available measured geophysical characteristic of the earthquake best correlates to the overall level of disruption experienced by these rural organisations? To answer these questions, two questionnaires were deployed to rural organisations in the affected region. The questionnaires asked about physical damage estimates, short-term organisational disruption estimates, and the factors that were found useful in mitigating the effects experienced.

3.5 Organisational vulnerability to earthquakes

Drawing from the body of literature on organisational earthquake vulnerability and impact studies over the last 20 years, e.g. [4, 111, 133, 210–212], several factors appear to be important to organisational impact and survival post-event. From generalized impact assessments and survival analyses to quantitative vulnerability assessments, these studies have catalogued earthquake-related impacts by identifying vulnerabilities through associated organisational attributes. This was done from a variety of theoretical frameworks and provides an initial outline to understanding how different types of organisations are likely to respond to earthquakes. From these works, the most commonly cited disruptive factors are extracted and used as a basis for analysis presented in this chapter.

Earthquakes impact organisations in a wide variety of ways, including: direct physical damage to structures or property, non-structural damages to premises, stock loss or damages, repeated critical service interruptions, halted or slowed production, changes in cash flow, staff attrition, and psychosocial effects on staff and family [3, 4, 109, 173, 213, 214]. In the United States and Japan, these disruptions have been found to be associated with organisational survival, as well as cumulative financial losses [110, 111, 215–219].

The most frequently cited disruption for organisations operating in a post-earthquake environment is the loss or interruption of critical services or lifelines. Following the

Northridge earthquake, approximately 25% of organisational dollar losses were attributed to utility disruption [109]. The duration of utility disruption, particularly electricity, has been found to be associated with dollar losses to organisations in the form of decreased revenue [172, 220]. Utility disruptions can also have cascading effects that decrease production, negatively affecting the entire regional economy [221].The rapidity that critical infrastructure is restored has been shown to directly contribute to definitions of community resilience to the effects of earthquakes [222, 223].

Organisations with fewer employees have been found to be more likely to close, and remain closed for longer periods of time [6, 111, 216, 224]. Small to medium size enterprises (SMEs) have fewer capital reserves to draw on following a disaster, and are forced to find coping strategies that are not capital intensive to maintain operations post-event [6, 110, 225].

Similar to financial capital, SMEs can also have limited social capital, which is the potential of accessing valuable resources through social connections such as professional and informal network relationships including family, friends, and neighbours [226]. Organisational use of social capital has been found to be a valuable asset both in terms of resolving internal organisational crises and rebuilding the organisation [227]. In terms of the use of the social capital, both personal and professional relationships are effective in the aftermath of a natural disaster [228], and employing these resources can expedite the transition from the organisation's emergency response to the recovery phases [227]. Furthermore, organisations that are able to effectively utilize network resources are better able to better adapt to the crisis environment [229].

The disruption of critical services and organisational size frequently aligns with sector-specific organisational vulnerabilities and therefore is important to consider. Several studies have found that industry sectors respond differently to the effects of earthquakes [109, 111, 219]. In a study of organisations in the cities of Santa Cruz and Oakland, Kroll et al. [3] found that following the Loma Prieta earthquake, single location retail trade sectors experienced proportionally greater losses and had more difficulty recovering than other types of organisations. These losses were largely attributable to customer access and service delivery challenges. Even if there is no direct physical damage to the organisation, issues such as disruption to the transportation network can inhibit customer and supplier access to the site [109].

Related to industry-sector vulnerabilities, neighbourhood effects, such as the damage state of neighbouring or nearby organisations, have also been observed to play a role in organisational recovery post-earthquake. Following the Northridge earthquake, it was found that organisations located in areas that experienced higher intensity shaking were less likely to recover [109]. This was true irrespective of individual organisations damage state, and neighbourhood effects, such as the overall damage state of the neighbourhood [173]. Even customer perception of an area's damage state can affect organisational recovery [173]. Evidence in support of these findings were also observed in Christchurch, as presented in Appendix A. In a post-disaster context, the neighbourhood effects in heavily damaged areas proved to be more significant than the damage state of an organisation; an organisation's recovery can be affected if it is located in a severely damaged area, even if the organisation itself did not suffer any damage [4, 109].

Lessons learned from studies analysing the effects of earthquakes on urban organisations show that major vulnerabilities stem from factors that are often sector specific and geographically driven. While common vulnerabilities exist across multiple sectors, each sector has specific characteristics that can be important in understanding likely patterns of disruption. The results of previous earthquake impact studies indicate the need to catalogue the impacts of an earthquake on farming and rural non-farming organisations.

3.5.1 Farming organisations and natural hazards

Overall, farming organisations are most affected by the direct effects of natural disasters when the core base of production is threatened (e.g. whether or not the grass can grow) [10]. The core base of production is threatened by environmental changes, such as during drought, flooding or snowstorm events, where paddock or dry matter production is slowed, quality is decreased or access to it is inhibited [10]. In the case of drought in Australia, the most significant negative financial impacts to farms occurred when output of the property was reduced [18]. Edwards et al. [18] also found the effects of decreased property output extended beyond the farm to the household, significantly decreasing household financial positions of farmers, farm managers and farm workers. Property output, and consequently direct monetary losses were observed as a direct result of flooding events [14]. The disruption to the core base of production represents the greatest vulnerability to regional farming organisations and is present for the dairy, mixed livestock and arable sectors.

For all sub-sectors, the degree to which farms are affected by natural disasters is time-sensitive. Farming vulnerabilities change as operations change over the course of a year, and may spike at particular times of the year when disruption of farming operations can be devastating to profitability, such as when livestock are being born or during periods of significant crop growth [128]. Importantly, periods of sensitivity are unique for each agriculture sector, and examples of sectors experiencing proportionally higher losses can be observed across different types of natural disasters [128, 230].

On-farm structures vary by sector, but in general are comprised of silos, equipment sheds, fencing, and often the homestead of the farmer. Dairy farms have milking sheds and storage tanks that are reliant on electricity to operate and most sectors have paddock production land which in the dairy and mixed livestock sectors, is often used as feed for the farm's livestock. The disruptive effect of damage to on-farm infrastructure is also seasonally dependent, such as the heavy reliance on water supply infrastructure for pasture- and crop-land irrigation and livestock water supply during the summer months in Canterbury. Livestock safety can also be threatened as a result of damage to built infrastructure such as fencing, dairy or livestock sheds, silos, and irrigation lines [231].

For dairy farming, the greatest vulnerability is the farms' need to produce on a daily basis without interruption [232]. Dairy sheds (the structure where the cows are milked) are necessary for this production as well as to maintain livestock health, and are reliant on electricity for production and storage purposes [233]. Milk produced must be transported off-site by tankers for processing and therefore dairy farms are susceptible to loss if the transport network is rendered inaccessible despite production continuing normally.

Vulnerabilities for the mixed livestock sector can be associated with livestock health, which can be threatened by water and feed availability [234]. Feed availability can be related to paddock damage if dry matter production or quality decreases [127], damage to structures which contain feed, or damage to the transport network if external feed is required. The arable sector is vulnerable to disruptions in water services and ground surface damage, which decreases dry matter production [235]. Farms from all sectors are likely to have grain silos, equipment sheds, and irrigation infrastructure that may be damaged by strong ground motion. Damage to these structures can contribute to seed, equipment and water inaccessibility, and require loss in productive time to repair or return assets to their pre-earthquake state.

Recovery from a disaster, for all sectors can be time and labour intensive. Returning the farm to pre-event productivity levels, let alone incorporating improvements to address organisational vulnerabilities can tax limited human and financial resources, or be exacerbated by external circumstances such as utility disruption, damage to the roading network or school closures [14]. Repairing fencing requires sourcing materials, and is labour and time intensive. Incorporating fine sediment deposited during hazardous events (e.g. flood silt, volcanic ash, liquefaction ejecta, etc.) into the topsoil is time expensive and must be done shortly following deposition to minimize the overall impact to paddock growth [129, 150].

Farm-sector characteristics may not be the most important factors in farm organisational resilience to natural hazards. From a survey of 31 farm households, Smith [130] found the level of preparedness for the 2006 Canterbury snowfall event was unrelated to a variety of farm characteristics such as: type, size, length of residence in region or experience with snow. Instead, the level of preparedness was found to be controlled by the personality attributes of self-reliance and independence [130]. While some farmers reinforced the importance of self-reliance and independence from external assistance measures, others mentioned that feed transport subsidization would be welcomed [130]. The farms sampled in the study maintained expectations of some assistance from Civil Defence when essential services were disrupted. This study illustrates that many farming organisations hazard and disaster management practices are more likely a reflection of the individual farmer's personality, and not that of an organisational characteristic. In addition, it highlights the need for farmers to have back-up systems in place if critical services were disrupted and that farmers hold expectations of governmental assistance following critical service disruptions [130].

In summary, farming organisations are vulnerable to production decreases, which have been found to decrease organisational viability over the long term and negatively impact local businesses and communities. With specific regards to factors that can lead to decreases in production, farming organisations show sector-specific vulnerabilities that can change over the course of the year. When affected by a crisis, farming organisations are often heavily reliant on a relatively limited workforce to contribute very high workloads for extended periods of time in order to mitigate and recover from the effects of the event. The studies that contribute to our understanding of farm vulnerability to natural hazards are based on studies of the impacts of meteorological and volcanic hazards. No studies have explicitly analysed the effects of an earthquake on farming organisations and consequently only theoretical evidence is available to predict likely outcomes.

3.5.2 Rural organisational resilience

Organisational resilience is the capacity of the organisation to adapt to disturbances; maintain the core operations, structure, identity and feedbacks; and seize opportunities emerging from the changed environment [56, 236]. The organisation's ability to dynamically adjust to the changing environment or its adaptive capacity is an integral constituent of organisational resilience [236, 237].

Some limited evidence in the organisational resilience literature suggests that certain types of organisations are more adaptable post-disaster [120, 238]. Rural organisations and those in the primary sectors prefer to focus on their adaptive capacity rather than planning, with high use of social, informal, and family networks to operate following natural disasters [148, 239]. The same pattern of adaptation has been observed for rural family-run organisations.

In studies conducted in New Zealand and the US, rural family run farming and rural non-farming organisational financial and social health was found to be coupled to the financial and social health of the local community [137, 240, 241], and rural organisations were sensitive to changes in social capital [242]. During natural disasters, family systems are often stressed in coping with the challenges faced by the recovery. For farming organisations that employ family members, disasters negatively affect both the family and organisational systems [241]. Also, the delineation between family and organisational resources is often blurred. In the United States, Winter and Fitzgerald [243] found the practice of bootstrapping, or the transfer of family financial resources to the family's organisation, occurred in nearly half of family owned organisations during normal operations. During natural disasters however, resources are often required for both family and organisational recovery purposes [137].

In New Zealand, rural communities are declining in population and potentially, in community resilience as funding for public spaces continues to fall [14, 160, 239], suggesting that community resilience is determined –in part– by funding for public spaces. Rural community resilience is bolstered through social engagement and community spaces, such as shared experiences of an area, a sense of belonging, or simply the presence of a community school [244, 245]. This sense of belonging has direct implications for local organisations as farmers have been found to prefer local suppliers [246] and there often lacks a delineation between rural economic and social spheres for farming organisations [245]. The engagement of farmers in informal socialization is important for the individual as well as the organisation following natural hazards as a mechanism to decrease stress, and reduce mental health issues [130, 245].

3.5.3 Rural organisations in the Canterbury Plains

As industry sector vulnerabilities are associated with organisational impacts of disaster, it is helpful to discuss the context of the rural industries in the Canterbury Plains. The majority of farms in the region are small, with less than 40 hectares, and on average employ 4 staff. Approximately 25% of farms in the Canterbury Plains are between 100 and 400 hectares in size [247]. The three most common farming industry sectors in the Canterbury Plains in descending order are: mixed livestock farming (a broad category encompassing sheep and cattle farming that comprises approximately 49% of farms), dairy farming ($\approx$ 22%), and arable farming ($\approx$ 16%) respectively [247]. Less common farm types in the region specialize in more exotic livestock, such as deer, llama and horse farming. Predominately pastoral, regional farms are increasingly capital intensive, typically utilizing some form of irrigation or local water source, and are reliant on built infrastructure, technology, and critical services [247, 248].

Due to New Zealand's economic neo-liberalization and deregulation in the mid-1980s, farming organisations moved from a relatively protected, low-risk, high income environment to an unprotected, high-risk, low income environment [160]. To offset some of the risk, the Ministry of Primary Industries (formally the Ministry of Agriculture and Forestry or MAF) initiated government-sponsored support structures available following adverse events, which includes among others tax deferment plans, discounted relief labour, and Rural Support Trusts or Groups. Rural Support Trusts are regionally distributed organisations staffed by local representatives specifically tasked to assist rural communities during and following an adverse event.

Following the Darfield earthquake, the Rural Recovery Group (RRG) was established by the then MAF (now MPI) and the Selwyn District Council, under their Civil Defence and Emergency Management powers [249]. Its task was to assess impacts and needs of affected farming organisations and coordinate available assistance. It was comprised of public and private organisations, which included industry groups, farm-support industries, and the North Canterbury Rural Support Trust.

Unlike farming organisations, rural non-farming organisations are not specifically within the purview of MPI or Rural Support Trusts. The rural non-farming organisations in the Canterbury Plains region are diverse, with complicated and nuanced social and economic linkages to the farming sector [160, 240]. For most of the 20^{th} century, farms comprised the majority of organisations in the Canterbury Plains region. However following the neo-liberalization of New Zealand's economy in 1984, farm numbers in New Zealand have been in decline [250], farm productivity and efficiency has increased, and the economic coupling between the farming and rural non-farming industry sectors has loosened. Rural non-farming organisations in New Zealand were often support organisations for the agricultural sector, however this association has become less predominate in recent years with the growth of other industry sectors such as rural tourism that are not directly associated with the primary producers.

As of 2012, 60% of the regional organisations were non-farming organisations with an average of three employees [251]. The most common rural non-farming industry sector in the Canterbury Plains region was rental, hiring, and real estate services. The sector includes approximately 19% of organisations in the region, but only employs 1% of the regional workforce as they are predominately single person operations. Of the rural non-farming sectors, manufacturing was largest employer, encompassing 14% of the regional workforce and averaging 12 employees per operation. The remaining industry sectors comprise less than 10% of regional organisations and 10% of regional employees, which illustrates the wide breadth of industry sectors in the region [251].

3.6 Methods

The study presented in this chapter focuses on organisations located in the Canterbury Plains (Fig. 1). Two types of organisations were defined and sampled for the purpose of this study: farming and rural non-farming organisations. For this study, farming organisations included dairy, sheep and beef, arable, and mixed among other sub-categories. The other sub-categories were primarily less common livestock farming, such as horse or alpaca farming.

All remaining organisations in sectors not defined as agriculture under the ANZSIC 2006 convention were broadly categorized as rural non-farming organisations, which include cafés, retail outlets, and manufacturing among others. These rural non-farming organisations were located in small rural towns where agriculture represents a significant portion of the surrounding organisations. The sample area and the locations of responding organisations are shown in Figure 3.1. This categorization served to test whether the impacts observed by farming organisations was consistent with the sectoral vulnerabilities of farming and not a product of being located in a rural environment.

To capture organisational impact data following the 4 September Darfield earthquake, 2 questionnaires were deployed. The first questionnaire, the Farm-specific questionnaire (included in Appendix C as the "Farm Specific questionnaire"), was distributed only to farming organisations. The second, the Resilience questionnaire (RQ) (included in Appendix C as the "Canterbury questionnaire"), was deployed to both farming and rural non-farming organisations. Two questionnaires were used – one specifically designed for rural organisations and another designed for both urban and rural organisations – in order to better collaborate with a multi-sectoral study sampling organisations in Christchurch. The multi-sectoral study initiated shortly after the deployment of the Farm-specific questionnaire, which also assessed the disruptive nature of the earthquake to organisational vulnerabilities. Items from the RQ were designed to be comparable to the Farm-specific questionnaire. Thus, the core vulnerability, mitigation, and impact questions explained above were consistent. No personal data, including gender, age, or ethnicity were collected from respondents in either questionnaire as these factors, while potentially influencing, are considerations for later studies. Both questionnaires were approved by the University of Canterbury Human Ethics Committee (approval code HEC 2011/30) prior to deployment.

The Farm-specific questionnaire addressed issues of organisational disruption, strategies used to mitigate the effects of the earthquake, as well as perceived shaking directions, patterns of ground deformation, and changes in the water table. The Farm-specific questionnaire was administered online and was made available through a governmental support website frequented primarily by farmers and was also distributed through Federated Farmers, New Zealand's largest independent rural advocacy organisation. No time constraint was provided, but only valid responses received between 30 September and 26 October 2010 were used. The distribution was not restricted to a specific geographic area, but only responses from farms located in the Canterbury Plains are reported in this study.

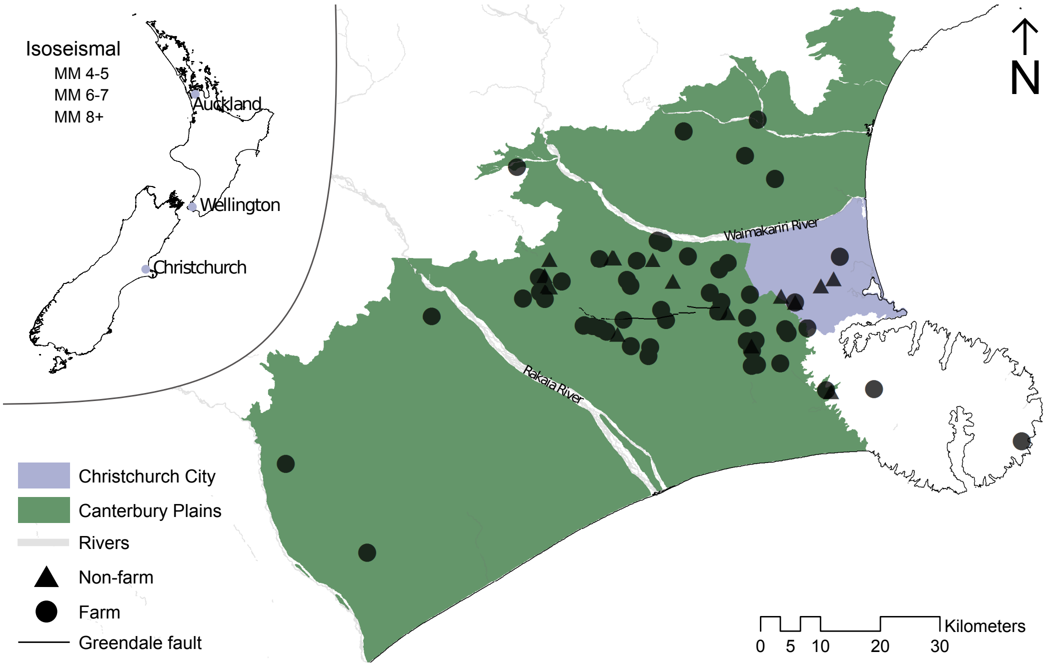

Figure 3.1: Locations of sampled organisations in relation to the Canterbury Plains, the city of Christchurch, the Darfield earthquake structures and the major river systems in the region.

The RQ was distributed to all farming and rural non-farming organisations along 25km long transects running perpendicular to the fault surface expression as a means to assess the direct impacts on organisations at increasing distances from the scarp. These transects crossed intensive farmland as well as farm support towns. In total, questionnaires were distributed to 142 farming organisations and 155 non-farming organisations. Importantly, the vast majority of rural non-farming organisations were located in rural support towns proximal to the epicentre that experienced strong ground-motion. The RQ was deployed first by delivering a hard copy of the questionnaire to the organisation's physical address, and then followed up with a telephone call. When potential respondents were reached, they were presented with the option of completing the questionnaire over the phone, online via an online survey engine, mailing back the hard copy with a prepaid envelope, or completing a soft-copy version online and emailing their response [192]. Organisations were given five weeks to respond to the questionnaires if they preferred not to answer by phone. Data collection took place between 16 November and 13 December 2010. Rural non-farming organisations were contacted between 10 AM and 4 PM. Farming organisations were contacted by phone on weekdays between the hours of 5 PM and 9 PM as the farmers were more likely to be reached then. A majority of farms (70%) that received hard copies of the questionnaire at their physical address did not have listed telephone numbers and were unreachable by phone. Both questionnaires assessed impacts by identifying different types of damage or disruption (e.g. structural damage, non-structural damage, electricity disruption, communications disruption, etc.) and asking the respondent to rank the level of disruption caused by each impact. The ranking of disruptiveness was assessed using a four point Likert scale: (1) not at all disruptive, (2) not very disruptive, (3) moderately disruptive, and (4) very disruptive. General organisational information was also collected to help better categorize the respondents. These items included the organisational sector, whether the organisation owned or leased the property from which it operated, the number of employees, and location. To assess mitigating factors, respondents were provided a series of factors (e.g. insurance, emergency management plan, neighbours etc.) and asked to report whether the factor was helpful in mitigating the effects of the earthquake. Respondents were also asked to report the single greatest challenge faced in the aftermath of the earthquake using an open-ended qualitative item. A generalized outline of items included in the questionnaires can be found in Table 3.1.

All data collected is post-event, subjective and self-reported. Data collected following the event is limited in that the pre-existing state of the organisation is unknown. The perceived impact to the organisation is also subject to the bias of the respondent, as some may under or over report organisational disruption levels based on factors such as personal stress levels. Respondents may have found a vested interest in under/over reporting disruption assessments, either to appear less affected than competitors or more affected to potentially attract attention or assistance from the government or relief organisations. This introduces a high level of variability in the data which cannot be

Table 3.1: Demographic, impact, mitigation items collected

Item Category	Data fields
Organisation information	Business sector
	Own/lease property
	Number of employees
	Location
	Age of organisation
Organisation impacts	Impacted (Yes/No)
	Structural damage[1,3]
	Non-structural damage[3]
	Inventory or stock damage[3]
	Lifeline disruption[2,3]
	Damage to or closure of nearby organisations[3]
Mitigating factors[3]	Backup/alternatives to lifelines
	Relationship with supplier
	Relationship with staff
	Relationship with bank or lender
	Relationship with neighbours
	Available cash or credit
	Insurance
	Business continuity, emergency management or disaster preparedness plan
	Practiced response to a disaster
Financial data	Change in revenue

[1]Structural damage consisted of damage to integrity of structures used in the organisation. For farming organisations, specific farming structures and the farm household was included.
[2]Lifeline disruption included electricity, water, sewerage, and communications.
[3]Four disruptiveness levels were used in quantifying the disruption to the organisation, which include: not at all, not very, moderately, and very disruptive. The same four-level scale was used to assess different factors' mitigating effects (e.g. How helpful was having available cash or credit in mitigating the effects of the earthquake?)

constrained; however there is no evidence to support a significant positive or negative bias in the dataset.

3.7 Results

Four questions are addressed in this section: (1) how were farming organisations affected in comparison to rural non-farming organisations? (2) were farming organisations affected in a similar manner to rural non-farming organisations? (3) what factors were found to be helpful in mitigating the effects of the earthquake? and (4) do the degree to which organisations were affected by the earthquake correlate to any geophysical datasets? The analysis first outlines the types of disruption common to the farming organisations and highlights different patterns of disruption found for rural non-farming organisations. These patterns are then used to establish single index impact scores for farming and rural non-farming organisations. The single index scores are then compared to earthquake data. This is done to see if any measurable geophysical parameter correlates to the level to which organisations were impacted by the event. Lastly, the factors that were found to mitigate disruption to the organisations are then analysed for both farming and rural non-farming organisations.

In total, 78 responses were collected from the two questionnaires. Sixty-nine per cent of responses ($N = 54$) were recorded from farming organisations and rural non-farming organisations represented 31% of the sample ($N = 24$). The farming sample was mostly populated by mixed livestock farms (32%), followed by dairy (18%), and arable (9%). The remaining 10% was a combination of niche farm types that for example specialized in less common livestock (deer, horse, llama, etc.). As shown in Table 3.2, the proportion of different farm and rural non-farming organisations sampled are consistent with the Canterbury Plains region. The sampled rural non-farming organisations were represented by a wide array of industries. No single sector represented more than 5% of the total sample of rural non-farm organisations. The industries comprising the rural non-farming sample included hospitality, manufacturing, retail, and service. Other industries that represented less than 4% of the sample included construction, education, fast-moving consumer goods, health, media, education, and religious services. The Rental, Hiring and Real Estate Services sector was under-represented in this sample.

While farming and rural non-farming organisation samples were primarily comprised of SMEs, farming organisations employed fewer people overall. Seventy-five per cent of rural non-farming organisations employed fewer than 23 full time staff, and two very large organisations employed over 100 employees. In contrast, the largest farming organisation

Table 3.2: Sampled farm and rural non-farming sectors compared to regional organisations [252]

		Canterbury Plains		Sample	
Sample	Sector	N	%	N	%
Farm	Arable	591	6%	7	9%
	Dairy	797	8%	14	18%
	Mixed	1742	18%	25	32%
	Other	458	5%	8	10%
Non-Farm	Mining	15	0%	0	0%
	Manufacturing	346	4%	3	4%
	Electricity, Gas, Water and Waste Services	27	0%	1	1%
	Construction	813	8%	2	3%
	Wholesale Trade	270	3%	0	0%
	Retail Trade	335	3%	2	3%
	Accommodation and Food Services	246	3%	4	5%
	Transport, Postal and Warehousing	248	3%	0	0%
	Information Media and Telecommunications	34	0%	1	1%
	Financial and Insurance Services	481	5%	0	0%
	Rental, Hiring and Real Estate Services	1866	19%	1	1%
	Professional, Scientific and Technical Services	437	4%	2	3%
	Administrative and Support Services	188	2%	0	0%
	Public Administration and Safety	67	1%	0	0%
	Education and Training	142	1%	2	3%
	Health Care and Social Assistance	184	2%	2	3%
	Arts and Recreation Services	196	2%	2	3%
	Other Services	297	3%	0	0%
	No Response	-	-	2	3%
Total	Farm	3588	37%	54	69%
	Non-Farm	6192	63%	24	31%
	All Sectors	9780	100%	78	100%

had five staff members (including the farmer). Farming organisations were also more likely than rural non-farm organisations to own their property and buildings (Fischer exact p, two-tailed $p = 0.0306$).

3.7.1 Farming organisational impacts

A majority of farming organisations (62%) identified being affected by the event. For all farming organisations, the most common infrastructure that suffered structural damage were homesteads (43%), grain silos (43%) and wells, water tanks or water races (29%).

In 7% of cases, structural damage was a direct result of liquefaction. Irrigation infrastructure were often damaged due to the ground motion, while fence-lines were often damaged in areas where surface deformation were observed.

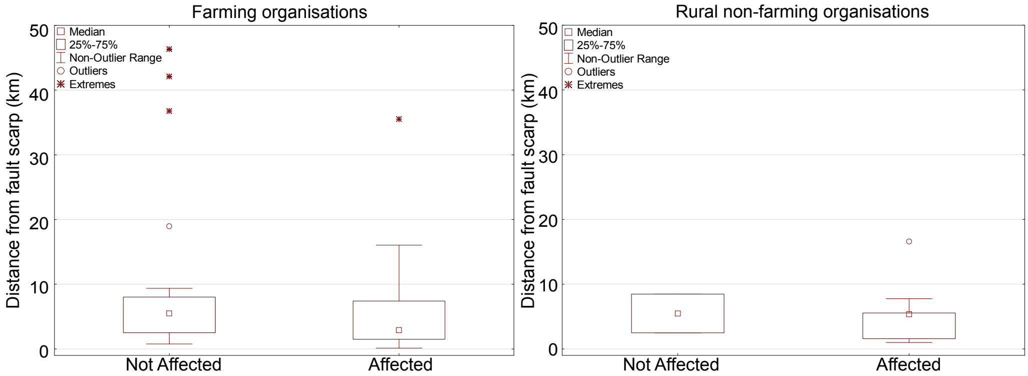

FIGURE 3.2: Sampled organisational distances from fault scarp broken down into farming and rural non-farming cohorts.

Farming and rural non-farming organisations near the fault scarp were not more likely to report being affected. As shown in Figure 3.2, the organisation's distance from the fault scarp did not correlate with the likelihood of being affected.

Farming organisations proximal to the fault scarp observed surface deformation in the form of new hills, scarps or cracks. Surface deformation was primarily lateral, although there was some vertical displacement. Deformation was evident from paddock rupture, misaligned or broken fencing, irrigation infrastructure damage, farm track damage, and relief changes to paddocks that required remediation such as heavy rolling. Some examples of these impacts to farms are shown in Figure 3.3.

Liquefaction was not commonly observed in the farming sample as only 13% reported finding material deposits. Of those affected by liquefaction, the most commonly reported challenge was the time and energy required to reincorporate the deposits into the topsoil. One household experienced differential settling underneath the foundation which rendered the homestead unlivable and consequently disrupted farm operations.

Other patterns of deformation reported were changes in the water table which caused flooding in localized areas, surface cracking, changes to farm boundary lines, and in one case, surface flooding caused by the fault scarp's vertical displacement to a river channel.

The most severely disruptive impacts to farms were interruptions to electricity and water services, and structural damage to on-farm infrastructure. Water services for most farms

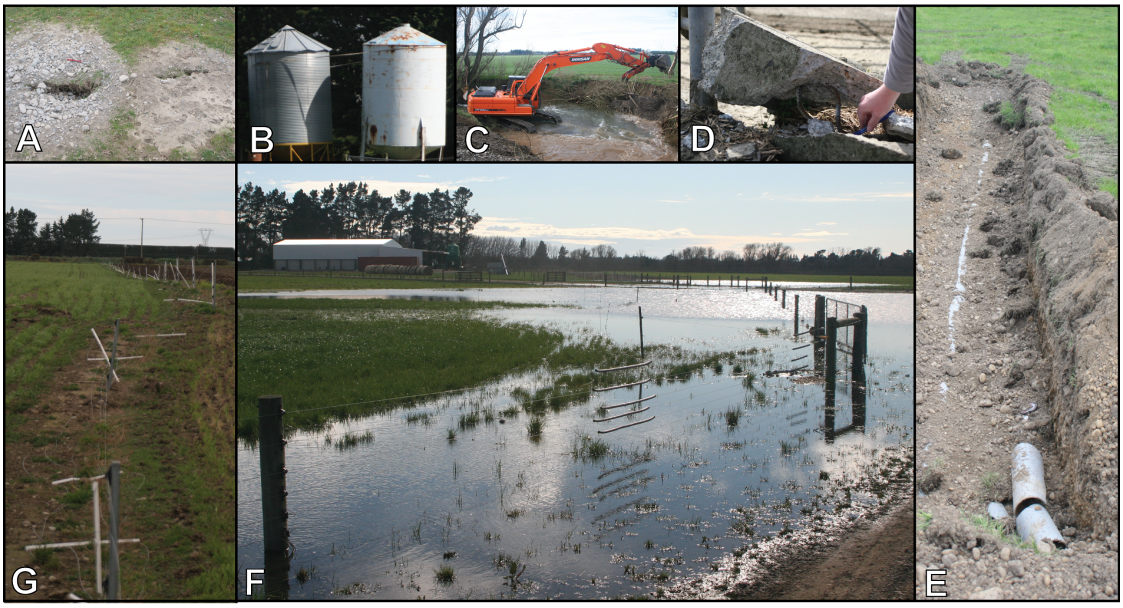

Figure 3.3: Examples of earthquake-related impacts to farming organisations following the Darfield earthquake. (A) damage to buried water infrastructure. (B) two grain silos strapped together due to listing in opposite directions.(C) damage to dairy shed concrete block. (D) paddock surface flooding. (E) fence damage and fault offset. (F) deepening of river channel due to scarp offset. (G) liquefaction deposits. (H) lateral offset of drainage channel and surface rupture paddock damage.

were local wells, tanks or water races. Water services were disrupted due to damage to the well structure, tank damage, increased water turbidity, or changes in the water table. The event occurred at a time of year when irrigation was not necessary for farms in Canterbury. Thus, the primary impact was in the decreased availability of water for livestock.

Dairy farms in particular found electricity disruption and structural damage to be very disruptive to operations. Of the dairy farms that reported being very affected by electricity disruption, none had a generator available. The only sampled dairy farm that had a generator available reported the electrical service interruption to be not very disruptive to operations and specifically identified the use of the generator as helpful in mitigating the effects of the earthquake. Dairy farms that reported catastrophic structural damage to their milking shed or that had no capacity to milk due to power outage arranged to relocate herds to neighbouring farms. These arrangements developed following the event and the neighbouring farm did not require compensation.

Mixed livestock and arable farming organisations showed a more equal distribution across the different types of impacts. So while dairy farms may exhibit a more acute vulnerability to electricity interruption and structural damages, mixed and arable farming were similarly affected by the event, and no farming sector proved to be more affected overall. Farming organisations did not report any major difficulties accessing supplies. Only one farm indicated that additional suppliers were required in the aftermath of the earthquake which were specific to recovery efforts as they noted that their normal suppliers were completely capable.

3.7.2 Rural non-farming organisational impacts

Nearly all rural non-farming organisations (92%) reported being affected. The majority of rural non-farming organisations sampled were from areas within 10 km of the fault scarp which experienced high intensity shaking, and consequently the sample is not representative of rural non-farming organisations throughout the Canterbury Plains region and likely overestimates the frequency with which rural non-farming organisations were affected by the Darfield earthquake.

Overall, the most severely disruptive impacts were interrupted electrical and communication services and non-structural damage. Rural non-farming organisations were also negatively affected by damage to or closure of neighbouring organisations. A complete summary of the most disruptive impacts for farming and rural non-farming organisations may be found in Table 3.3.

Rural non-farming organisations were much more likely than farming organisations to close, observe drops in revenue, or note changes to their customer base. Fifty per cent of sampled rural non-farming organisations closed for an average of three days. None of these organisations closed permanently. The most commonly cited reasons for closing temporarily were: needed to clear up damage to interior, building waiting to be structurally assessed, and stock loss or damage. Forty per cent of rural non-farming organisations saw decreases in revenue in the 3 months following the earthquake, with an average drop of 47%. Only 15% saw an increase in revenue, with an average difference of 16%. All non-farming organisations that experienced decreases in revenue also indicated either moderate or substantial decreases in the number of customers.

Table 3.3: The most disruptive organisational impacts related to the Darfield earthquake broken down by affected farming and rural non-farming organisations. The mean disruption percentage value is calculated by dividing the mean disruption value by the maximum possible (4) as a means to contextualize the mean integer value.

	Farming organisations (N=32)		Rural non-farming organisations (N=20)	
Rank	Impact	Mean Disruption	Impact	Mean Disruption
1	Elect. disrupt	2.1 ±0.89 (70%)	Non-struct. dam.	1.3 ±1.21 (42%)
2	Water disrupt.	1.7 ±1.11 (57%)	Elect. disrupt.	1.2 ±0.95 (40%)
3	Struct. dam.	1.5 ±1.05 (50%)	Equip. dam.	1.2 ±1.05 (35%)
4	Non-struct. dam.	1.3 ±1.12 (45%)	Stock damage	1.1 ±1.23 (35%)
5	Comms. disrupt.	1.3 ±1.03 (43%)	Comms. disrupt.	1.1 ±1.05 (35%)
6	Damage to equip.	1.1 ±1.21 (38%)	Nearby org. dam.	0.8 ±1.24 (27%)
7	Ground damage	0.7 ±1.06 (25%)	Water disrupt.	0.5 ±0.89 (15%)
8	Sewerage disrupt.	0.5 ±0.92 (18%)	Access challenges	0.4 ±0.81 (12%)
9	Stock damage	0.5 ±0.91 (16%)	Sewerage disrup.	0.2 ±0.52 (7%)
10	Access challenges	0.5 ±0.96 (15%)	Ground damage	0.1 ±0.32 (4%)
11	Injury to staff	0 ±0 (0%)	Injury to staff	0.1 ±0.31 (3%)

3.7.3 Mitigating factors

Organisations were asked to reflect on what may have mitigated the impacts experienced or the level of disruption that resulted from the impact. Farms found well-designed and well-built buildings, relationship with our neighbour, and insurance to be the three most helpful factors in mitigating the effects of the earthquake. In contrast, the most frequently cited mitigation factors identified for rural non-farming organisations were related to financing options and supply chain logistics. These results illustrate that relationships, whether between lenders or suppliers, prove to be very common mitigation technique for rural non-farming organisations. The complete results for all mitigating factors are shown in Table 3.4.

Farmers in the sample were well-insured, and at the time of sampling the vast majority of farming organisations rated their relationship with their insurer as neutral to very satisfied. Only two farms (5%) indicated that they were either dissatisfied or very dissatisfied with their insurer.

The most common forms of insurance coverage held by affected farming organisations were property and buildings, motor vehicles, and public liability. Nearly all (95%, $N = 39$) of affected farming organisations reported having property, building, and motor vehicle insurance. A majority (70%, $N = 29$) reported having public liability insurance.

Table 3.4: Frequency table of responses to the item: What factors do you think have helped you minimize the impact of the earthquake?

	Farming organisations (N= 41)		Rural non-farming organisations (N=19)	
Rank	Mitigating Factor	Freq.	Mitigating Factor	Freq.
1	Well-built buildings	76%	Lender relationships	72%
2	Neighbour relationships	71%	Supplier relationships	68%
3	Insurance	71%	Spare resources	56%
4	Emergency kit	49%	Available cash or credit	53%
5	Available cash or credit	41%	B.C./EMG. MGMT. plan	47%
6	Spare resources	39%	Emergency kit	33%
7	Staff relationships	34%	Staff relationships	33%
8	Supplier relationships	29%	Insurance	32%
9	B.C./EMG.MGMT. plan	29%	Different site	25%
10	Lender relationships	29%	Well-built buildings	17%
11	Planned disaster response	20%	Neighbour relationships	17%
12	Use of different site	15%	Planned disaster response	11%

One organisation reported having livestock coverage in the case of escape and injury due to passing vehicles. Farms that reported having cash flow, income protection, and organisational interruption insurance were likely to also have protection for organisation assets and equipment as well as coverage for commodities and goods. Farms that reporting holding "other forms of insurance" appeared to be underinsured as they were less likely to also have property and building insurance, motor vehicle insurance, and public liability insurance (correlations were strongly negative i.e. $r \leq -0.5, p < 0.05$).

Over 70% of rural non-farming organisations held property and buildings, organisation assets and equipment, and public liability insurance types. Those that reported having organisation assets and equipment insurance were also likely to have property and buildings and public liability ($r \geq 0.5, p < 0.05$). Similar to farming organisations, the overall levels of satisfaction of insurance packages and insurers were positive for rural non-farming organisations.

3.7.4 Biggest challenges

Common themes emerged from an open question that asked respondents to identify their biggest challenge(s). The most frequently cited operational challenge after the earthquake for farmers was stress. This was attributed to a combination of factors including sleep deprivation, wet ground conditions, physical damages sustained on-farm and the stress of managing the day-to-day activities. Irrigation concerns were also raised as a significant issue, commonly regarding the increased turbidity of well water. Dairy farmers reported experiencing increased stress levels as a result of concerns about stock welfare and the inability to milk stock as electricity disruptions affected the milking process. For dairy and mixed livestock farming, stock management was also of concern. Many fence lines were damaged and farmers experienced difficulty accessing damaged areas due to the wet conditions. Furthermore, there was concern for livestock breaking legs by stepping in cracks caused by surface deformation, although there were no reports of this occurring. These results suggest that the psychosocial trauma sustained by the event was of equal if not greater significance to the farmers' ability to maintain operations than was the physical impacts incurred on-farm.

Industry-sponsored literature and information was circulated advising farmers to avoid starting irrigators due to well turbidity levels. This created uncertainty among some respondents about damaging critical farm infrastructure. Because farms in the region were not irrigating at the time of the event, the overall impact of irrigation disruption was reported to be of significance; however, the likelihood of disruption during periods where irrigation is necessarily is high.

In contrast, the biggest challenge most frequently cited by rural non-farming organisations were maintaining cash flow immediately following the event. These cash flow challenges were based on organisations forced to close due to non-structural damages to their premises. Also, many organisations that experienced decreases in revenue attributed the change to decreased numbers of customers. The second most common biggest challenge cited by organisations was psychosocial, most commonly in the form of stress. A comparative summary of the biggest challenges for farming and rural non-farming organisations may be found in Table 3.5.

3.7.5 Organisational impact index

A single index score called organisational impact was created to assess the short-term impact to farm and rural non-farming organisations by quantifying the disruptive nature of direct and indirect impacts to the event. The items cited as disruptive by at least 50% of farming organisations, were used to focus on the most vulnerable aspects of farming and rural non-farming organisations. For rural non-farming organisations, there was

Table 3.5: Comparison of biggest challenge in the aftermath of the 4 September earthquake responses by farming and rural non-farm organisations.

	Farming organisations (N= 41)		Rural non-farming organisations (N=19)	
Rank	Biggest Challenge	Freq.	Biggest Challenge	Freq.
1	Stress	37%	Cash flow	39%
2	Water	20%	Stress	22%
3	Non-structural damage	11%	Stock management	17%
4	Cash flow	6%	Non-structural damage	17%
5	Electricity	6%	Structural damage	6%
6	Roading	6%	Roading	0%
7	Stock management	6%	Water	0%
8	Structural damage	6%	Communications	0%
9	Communications	3%	Electricity	0%

less of a consensus regarding the disruptive impacts, and consequently the top three disruptive impacts were used for comparative purposes.

The organisational impact index (OII) averages the three most disruptive items for farming and rural non-farming organisations respectively. As shown in Equation 3.1:

$$OII = \frac{1}{n} \times \sum_{i=1}^{3} \alpha_s \delta_{si} \tag{3.1}$$

With δ_{si} indicating the severity (s) of disruption (δ) for the instance of impact (i), and the impact weighting (α) to scale the disruption. Severity is the reported impact of a disruption (i.e. not at all, not very, moderately, very disruptive). The impact weightings are as follows: $\alpha_1 = 0$ ("not at all disruptive"), $\alpha_2 = 1$ ("not very disruptive"), $\alpha_3 = 2$ ("moderately disruptive"), $\alpha_4 = 3$ ("very disruptive"). The three most disruptive factors were also found to be significantly associated with all catalogued disruptions. As shown in Table 3.6, the calculated OII values are strongly correlated to the disruptive vulnerability for farming organisations, and to a lesser extent for rural non-farming organisations.

All the disruptive elements for farming organisations were significantly correlated to the OII metric. These correlations illustrate that the computation serves to generally approximate the variety of impacts farming organisations experience following the Darfield earthquake, with lower levels of precision for the less common disruptive elements and

Table 3.6: OII correlations to constituent disruptions.

	Farming organisations (N= 55)		Non-farming organisations (N=22)	
Rank	Disruption	Correlation	Disruption	Correlation
1	Electricity	0.910*	Telecommunications	0.935*
2	Structural damage	0.865*	Electricity	0.791*
3	Water	0.796*	Non-structural damage	0.715*
4	Non-structural damage	0.737*	Water	0.608*
5	Ground damage	0.668*	Equipment damage	0.586*
6	Telecommunications	0.624*	Structural damage	0.580*
7	Equipment damage	0.557*	Ground damage	0.477*
8	Access challenges	0.466*	Stock damage	0.294
9	Stock damage	0.457*	Access challenges	0.253
10	Sewerage	0.388*	Injury to employees	0.238
11	Injury to employees	-	Sewerage	0.147

* denotes $p<0.05$ Spearman R

may be suited as a first-order assessment for overall farming organisational impact for future events.

For rural non-farming organisations, the metric was not as effective in associating with all disruptions which is likely due to the small sample set and wide diversity in industry sectors represented in the sample.

3.7.6 Shaking intensities and the farming organisational impact index

Different geophysical parameters of the event were tested for association with organisational impact. The metrics examined were the New Zealand Modified Mercalli Intensity Scale (MMI) [253], Peak Ground Acceleration (PGA), shaking duration, frequency of aftershocks, and the magnitude divided by the aftershock depth. These metrics were projected against the locations of affected and unaffected organisations. All projections of geophysical data used the ordinary kriging method and the exponential semivariogram model. To isolate impact, all projected geophysical data were first examined to establish that sectoral or spatial properties of responding organisations were drawn from similar populations. No one sector reported being significantly more affected than the others, and all sectors showed normally distributed geophysical values.

MMI data were recorded through felt reports registered on the GeoNet website. The majority of felt reports were registered the same day as the earthquake and the population distribution did not change significantly with the addition of later reports. The MMI values that showed the greatest relative increases in the days and weeks after were MMI 7 and 8. However, the felt reports registered on the day of the earthquake populate a similar frequency distribution of MMI values, albeit with the omission of a small percentage of MMI 7 and 8. Therefore, data from the day of the earthquake are not significantly biased and could be used immediately following the event.

When asked as a simple yes or no, farms affected by the earthquake were located in areas of higher MMI values than unaffected organisations (Mann-Whitney $U = 3.78$, $n1 = 49\, n2 = 25$, $p = 0.000155$ two-tailed). Peak ground acceleration values were found to be weakly associated to the reported OII impact to farms. Furthermore, metrics that exhibited no association to OII were shaking duration, frequency of aftershocks or the average M_w divided by the depth of the aftershock epicentre.

It was found that the distribution of MMI values for the unaffected organisations was normal ($D = 0.0957$, $p < n.s.$, Lilliefors $p < 1$) while farms that reported being affected by the event showed a non-normal distribution of MMI values $D = 0.1575$, $p < 0.2$, Lilliefors $p < 0.01$). The two distributions also showed differences in locality, with affected organisations appearing to be more heavily concentrated in the higher MMI values. As shown in Figure 3.4, organisations that were located in regions with lower intensity shaking based on MMI values were more likely to report being unaffected than those farms in areas that experienced higher intensity shaking (Mann-Whitney $U = 150$, $n1 = 30\, n2 = 23$, $p = 0.000482$). The spread of the data is large and the distributions have large areas of overlap, making the identification of MMI value thresholds demarcating organisational impact not possible. However, the difference between the central tendencies (or modes) of the two distributions is distinctive.

Affected farming organisations that did not report their relationships with their neighbour helpful, on average, experienced shaking intensities of MMI 5.7 ($N = 7$, $Std.Dev = 0.8$). Affected farming organisations that found relationships with neighbours helpful experienced an average of MMI 6.1 ($N = 23$, $Std.Dev = 0.4$). However, the use of neighbour relationships appears to be controlled by the level of organisational disruption experienced or the intensity of shaking experienced. With regards to specific impacts,

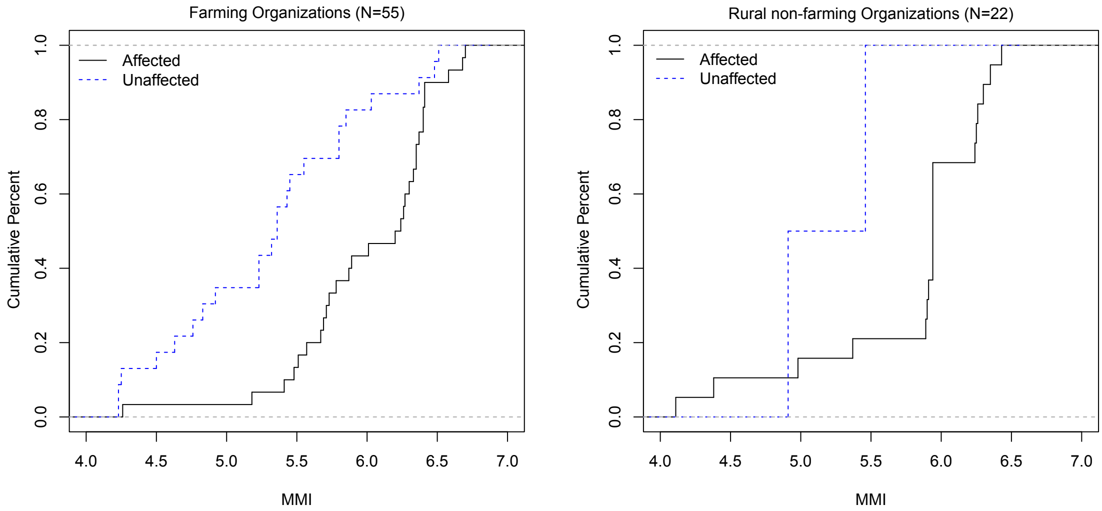

FIGURE 3.4: Empirical cumulative distribution functions of MMI values for affected and unaffected farming and rural non-farming organisations. Affected organisations were located in areas that experienced shaking intensities of at least MMI 5.

farming organisations were significantly more likely to use their neighbours in mitigating the effects of the earthquake when they experienced greater organisational disruption due to structural damages (Mann-Whitney $U = 100$, $n1 = 29$, $n2 = 12$, $p < 0.05$ two-tailed) and electricity disruption (Mann-Whitney $U = 103$, $n1 = 29$, $n2 = 12$, $p < 0.05$ two-tailed).

As shown in Figure 3.5, farming organisations show an increase in the use of neighbour relationships in mitigating the effects of the earthquake as shaking intensity increases. The use of these relationships also increases as organisations are increasingly affected. From these data, the use of neighbour relationships is used for both increases in experienced shaking intensities and organisational disruption, illustrative of the use of social networks to mitigate physical and organisational challenges alike. No such pattern was found for rural non-farming organisations.

3.8 Discussion

With the exception of electricity disruption, farming organisations showed a distinctive pattern of disruptive impacts when compared to those of rural non-farming organisations. On-farm infrastructure was shown to be vulnerable to ground shaking, localized flooding, and differential settling resulting from liquefaction. The disruption of water

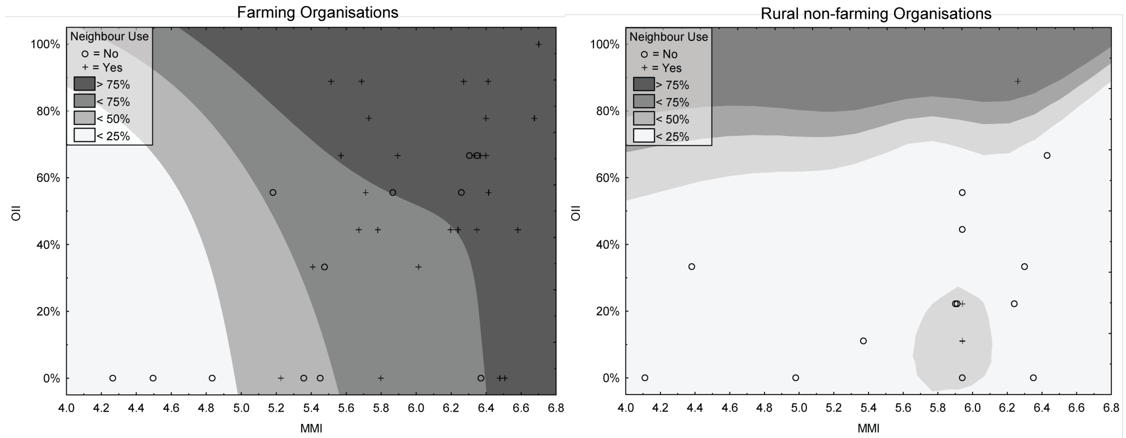

Figure 3.5: Comparative illustration of the relationship between total organisational disruption, MMI and the use of neighbours to mitigate the effects of the earthquake for farming and rural non-farming organisations. The likelihood of the farming organisation to find the relationship with their neighbour helpful in mitigating the effects of the earthquake is shown to increase with MMI values as well as OII scores. Comparatively, rural non-farming organisations show relatively little use of neighbour relationships that is not associated with MMI values.

services and structural damage to buildings were found to be more disruptive for farming organisations while rural non-farming organisations were more affected by non-structural damages and damage to equipment. While organisational disruption was strongly associated with electricity disruption for farming organisations, no correlation was found to revenue loss, which is surprising given documentation that illustrates the disruption of critical services to be a large cause of dollar losses following earthquakes for urban organisations [109, 172, 220]. However, farming revenue streams are better analysed at yearly or multi-year levels and therefore follow-up studies are required to better constrain the financial impacts. That said, it is unlikely that affected farms will observe large decreases in revenue as the most significant negative financial impacts occur when production decreases [18], which was not widely observed. Furthermore, as Ward [230] and Wilson [128] demonstrate, farms have different periods of vulnerability. The earthquake occurred during a period when irrigation was not necessary and therefore the disruption to irrigation infrastructure was minimal.

The overall level of disruption was not significantly higher for the dairy sector although the different farming sectors did show differences in the types of impacts experienced, similar to the findings of Tierney [109] and Chang and Falit-Baiamonte [111], reflecting that sectoral and subsector differences are relevant within agriculture and should be considered in analysis. For example, dairy farms were most susceptible to electricity disruption and structural damages, while mixed livestock and arable farms were often impacted by water supply challenges. Though organisations may have sector specific vulnerabilities, there was no evidence to support higher vulnerability of different sectors; however this may be due to the limited sample size. It is also unknown if smaller farming organisations were more vulnerable because the sample did not include medium to large scale industrial farms.

Rural non-farming organisations were similar to farming organisations in that electricity disruption was identified to be an important impact; however the most disruptive impacts were related to non-structural and contents damage. This reflects findings from studies of urban organisations [4].Comparable to the findings of Tierney [109], organisations were negatively impacted by damage to neighbouring organisations. For rural non-farming organisations, damage to neighbouring organisations disrupted operations, and neighbouring organisations were rarely cited as helpful in mitigating the effects of the event. These results are similar to what was observed for urban organisations in Christchurch, where organisations were frequently disrupted by damage to or closure of nearby or neighbouring organisations, as described in Appendix A or [254, 255].

Farming organisations did not cite neighbouring organisations as disruptive, but rather frequently utilized neighbours as assets in the recovery phase of the event and were very likely to find their neighbour helpful. These relationships were not only used for organisational means, as was the case for several respondents, but also as a personal support mechanism. Farmers found that speaking about experiences with neighbours, friends or loved ones was helpful in decreasing stress levels, frequently citing the common phrase “a problem shared is a problem halved” in interviews. These results concur with previous findings regarding the use of social capital as a recovery mechanism post-disaster [14, 226–228].

Neighbour relationships were not found to be employed in the rural non-farming organisation sample. It is unclear whether this difference was due to ecological factors, such as similar farming organisations located nearby and therefore more likely to work cooperatively, or if it is a sectoral phenomenon. However whether they were personal or professional, relationships were employed in the recovery phase as mitigation techniques by the majority of rural non-farming organisations, which supports the findings of Doerfel et al. [227].

The ability of farming organisations to mitigate or manage the effects of the event appeared to be relatively similar across farming sectors, but differed when compared to rural non-farming organisations. Farming organisations showed a high reliance on their ability to adapt following the event, which supports the findings of Rhodes et al. [148] and Smith and Krannich [239]. While several dairy farms required the use of alternative facilities, no farm cited having a pre-existing arrangement or contract to ensure the use of these alternative facilities. They all cited informal agreements and noted that they relied on their informal network to secure these alternative locations. It was very uncommon for farming organisations to cite the use of an emergency preparedness plan as useful in mitigating the effects of the event, and a surprisingly small percentage of farms had the use of an electrical generator on-site.

Farming organisations showed a heavy reliance on high workloads distributed over a small workforce following the event. Maintaining the personal safety of the farmer or staff is likely the most critical vulnerability to the adaptive capacity of the farm. The rural non-farming organisations appeared to utilize more similar means of recovery to organisations located in Christchurch than farming organisations, as illustrated in Appendix A and [254]. This may suggest that the effect of locating in a rural area is of less significance to the organisational resilience characteristics than the industry sector.

The analysis of MMI values generated from felt-reports has shown some promise in identifying likely areas of affected farming organisations. Affected farming organisations were significantly more likely to be located in areas of high intensity shaking than unaffected farms. However, this result also shows that there is not a clear shaking intensity threshold that will delineate the affected from the unaffected. Affected farming organisations were found across the entire shaking intensity spectrum, which may be due to anthropogenic factors such as the distributed electricity network, illustrative of the need for further impact assessments to fully understand the factors that are associated with earthquake vulnerability. The result that the MMI values of unaffected farms is distributed across the full range of reported MMI values also reinforces the notion that the vulnerability of farms is highly nuanced, and is not reducible to the broad level assessment used in this study. Farming organisations affected in the low end of observed MMI shaking intensities is a relative distinction. The lowest MMI value of an affected farm was above MMI 4. This level of shaking is sufficient to cause non-structural damages, which is a major cause of organisational disruption to both farming and rural non-farming organisations. Although affected rural non-farming organisations were not located in areas of significantly higher intensity shaking in this sample, it must be stressed that the sample was located in rural towns proximal to the epicentre and consequently, these results are not generalizable to the broader region. Of the rural non-farming organisations, an overwhelming majority were affected which is due in part to the geographically constrained sampling methodology.

Closure and downtime of affected organisations is a characteristic of rural non-farming organisations, whereas the farming sample reported no closure as an effect of the earthquake. This requires further investigation and elaboration. As illustrated in Appendix A, Kachali [254], and Stevenson [255], rural non-farming organisations cited similar levels of closure to the results of organisations in the city of Christchurch. These results are not translatable to the farming sectors, as no direct parallel exists between the two groups. While obvious, it is important to reinforce the point that farming organisations will not close in the same sense as rural non-farming or urban organisations. Thus alternative measures must be found to make meaningful comparisons. In making this comparison, a more effective method is to quantify the time it takes for the farming organisation to repair damages. This provides a figure that is relatable to closure or downtime for rural non-farming organisations while quantifying the time required by the farmer to return the farm to a normal mode of operations.

In managing the effects of the event, farming organisations were most affected by the psychosocial stress, which was largely attributed to long hours, trouble sleeping, and feelings of uncertainty. Although this was not explicitly cited in the results of this study, there is evidence to suggest that farmers valued discussing the event with others from personal interviews following the event. This observation aligns with prior research on farming organisations following natural hazards, where the inability to communicate with friends and neighbours proved to be a significant psychosocial stress [130, 245]. Comparing the greatest challenges of farming and rural non-farming organisations illustrates a difference between the two groups. In rural non-farming organisations, stress was second to cash flow as the most commonly cited greatest challenge faced.

Following the event, a successful technique in assisting farms was employed by a government sponsored farm support group called the Rural Recovery Group (RRG). In the response phase, the RRG sent representatives to area farms to assess the damage state of the farm and the health of the farmer and family using a short questionnaire. These interactions were observed by both the farmers and representatives from the RRG to be helpful in decreasing stress. The RRG also held information meetings for the rural community where scientific and industry advice was disseminated to the affected community. These were well received as they were effective means to deliver up to date, industry and location specific information to the community while also providing a forum for farmers to socialize following the meeting. In follow-up interviews, the socialization periods of the meetings were found to be a successful mechanism in decreasing stress levels. In contrast, the greatest challenge cited by rural non-farming organisations was maintaining cash flow in the aftermath of the event, which was not commonly cited by affected farms.

3.9 Conclusions

Sampled farming and rural non-farming organisations were affected and responded to the earthquake differently. Rural non-farming organisations were most affected by non-structural damages, were most focused on maintaining cash-flow and employed formalized channels of recovery such as banks or insurers. In contrast, farming organisations were most affected by electricity disruption, were most challenged by psychosocial stress, and relied most heavily on their informal network to recover from the event. Different farming sectors showed relative differences in the types of impacts experienced, often related to vulnerabilities in the farm's core base of production. The nature of the disruptions to the farming organisations were related to the ability of the farm to continue producing that require the attention of the farmer. The results illustrate that not only were farming organisations affected differently, but also that the mechanisms and techniques employed by farming organisations were fundamentally different when compared to rural non-farming organisations. Rural non-farming organisations were affected and recovered in a similar fashion to organisations in Christchurch.

Despite the many differences, the reliance on electrical services was observed to be a critical vulnerability for both farming and rural non-farming organisations and back-up alternatives, such as on-site generators, were very helpful in mitigating the effects of the disaster. These results highlight the necessity of back-up alternatives to critical services across all sectors as an important component to organisational emergency management plans. Farming organisations relied heavily on their adaptive capacity as a means to recover from the event and would benefit through the development of their planning strategies. Formal or informal emergency planning strategies, such as the inclusion of back-up locations, would decrease downtime of operations and decrease the overall impact of the event on the organisation.

Because a large number of farming organisations utilized informal networks as a means for organisational recovery, socialization appears to be a critical factor in rural organisational resilience. Mechanisms to strengthen informal ties through community building events are likely to yield positive results in terms of increasing the size of farmers informal networks or strengthening pre-existing ties. Increases in community services and spaces should be viewed not only as functions for community development, but also as a means to increase farming organisational resilience.

With regards to the recovery effort, stress was one of the largest challenges for organisations affected by the event. Combined with the fact that the farmer is the most critical vulnerability to the organisation, psychosocial support in the aftermath of the event should be a priority of recovery agencies. In post-event interviews, one technique that was reported to be very effective was the RRG's initiative to personally visit farms in the affected region to assess the state of the organisation, and most importantly, the state of the farmers and their families. This was very well received by those visited and should be repeated in future events. In addition, information meetings which disseminated industry and scientific advice were effective in not only delivering up-to-date information, but also as a means to bring the community together. In targeting the most affected farming organisations, recovery agencies should consider prioritizing their efforts in areas of the highest intensity shaking. This method will improve the likelihood of reaching affected organisations. However, affected organisations will also be located in areas of lower intensity shaking, and that ideally all areas of MMI 4 or greater should be contacted if possible.

Future work is required to determine whether the effects found in this study persist, evolve over time, or subsequent challenges arise. Additionally, while farming organisations located in areas of higher intensity shaking were found to be more affected, asset repair cost data should be collected once available to determine (1) whether any association between repair cost and shaking intensity exists, and (2) if this association could be modelled to forecast asset losses for future events. These data would also serve to determine whether asset repair costs directly affect rural organisational performance, revenue or profitability in the years following. Finally, further natural hazard impact assessment studies that focus on rural organisations are needed so that impact comparisons can be drawn between different types of natural hazards.

3.10 Acknowledgements

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Chapter 4

Rural organisational recovery following the Canterbury earthquake sequence: mitigating strategies and the use of social capital

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4.1 Overview

This chapter discusses the experiences of farming and rural non-farming organisations over the course of the Canterbury earthquake sequence, contrasting the short-term impacts discussed in Chapter 3 with the medium-term impacts collected in the subsequent questionnaire. Furthermore, this chapter discusses the evolution of approaches taken by affected organisations in mitigating the effects of the aftershock sequence.

The theoretical framing in this chapter is largely grounded in ecological resilience theory, viewing organisations as constituent parts of a larger system wherein which multiple stability states can exist. Therefore the mention of resilience is attributable to the ecological resilience definition as explained in Chapter 1. In determining factors affecting systemic (the community of rural organisations) resilience, the SUST vulnerability model was employed, and a paradigm comparable to Smith [14] is used.

4.2 Contributions

Mr. Whitman designed the distribution methodology, conducted the data collection process, and performed the data analysis. The questionnaire was developed by Mr. Whitman, Mrs. Stevenson, and Ms. Kachali in collaboration. Dr. Wilson, Dr. Seville and Dr. Vargo advised the questionnaire development process, the distribution design, and data analysis, as well as contributed comments and revisions to the manuscript.

4.3 Abstract

This chapter investigates the response and recovery strategies employed by rural organisations affected by the Canterbury earthquake sequence in South Island New Zealand. In 2010 a M_w 7.1 earthquake occurred near the town of Darfield in the rural area west of Christchurch, and initiated thousands of aftershock in the years following. The earthquake sequence caused loss of life, repeatedly damaged built-infrastructure, and intermittently disrupted critical services. This chapter presents the survey results of rural organisations sampled in 2010 and again in 2012 regarding how they responded to the effects of the earthquake sequence, what types of planning strategies were used,

what resources were found to be most useful in mitigating the impacts of the event, and how responses evolved over the course of the sequence. The results show that the level of formalized emergency planning strategies for rural organisations are found to be low and the experiences of the earthquake sequence did not spur the development of emergency planning strategies. Organisations were more likely to have adaptive responses to the earthquakes, heavily relying on informal resources such as social capital to solve a variety of challenges ranging from logistics to stress. The results also show that the earthquake sequence had no measurable impact on organisational performance for the vast majority of rural organisations sampled.

4.4 Introduction

On September 4, 2010, a M_w 7.1 earthquake occurred near the rural town of Darfield, approximately 45 km west of Christchurch, New Zealand. Later named the Darfield earthquake, the earthquake produced peak ground accelerations that exceeded 1g [200], and created a surface fault line over 30 km long that consisted of horizontal and vertical offsets of 5 meters and 1 meter respectively [129, 199]. Liquefaction from the event caused differential settling and lateral spreading which damaged building foundations and critical infrastructure [256, 257], while the deposits covered paddock growth [129].

The impacts of the event caused infrastructure damage, disrupted transportation networks, and caused utility service outages [201]. The earthquake also initiated thousands of regional aftershocks in the following years [205]. Referred to as the Canterbury earthquake sequence, these aftershocks caused on-going episodes of severe ground shaking, surface rupture, liquefaction, and localized flooding which led to infrastructure damages, critical service interruptions, and during the strongest aftershocks, loss of life [258]. The most notable aftershock of the sequence was the M_w 6.3 earthquake on 22 February, which caused loss of life and the most extensive damage in the city of Christchurch [259]. For a complete review of the Canterbury earthquake sequence, see Bannister and Gledhill [260].

In the affected rural areas west of Christchurch, community meetings were held to disseminate information for farming organisations regarding how to best manage the effects of the earthquake [206]. While these meetings served to disseminate best-practice management advice, there was little empirical evidence from past events on how rural organisations can prepare for or respond to an earthquake. Few studies have addressed how rural organisations recover from the effects of a major earthquake, or what mitigating strategies are employed in response. Furthermore, there are no examples of studies analysing how these responses may evolve during a protracted aftershock sequence.

The purpose of this chapter is to document the responses and recovery strategies of rural organisations over an 18 month period located in the Canterbury Plains region of New Zealand to the Canterbury earthquake sequence. It examines affected rural organisations' emergency planning strategies, the mitigating strategies employed, the means of financing organisational recovery, the greatest challenges faced, the impact to organisational performance and how organisational responses evolved over the course of the earthquake sequence. This chapter contributes to the growing body of studies that seek to elucidate the effects earthquakes can have on businesses or organisations, e.g. [4, 6, 105, 109, 111, 173, 217, 261, 262]. It also seeks to contribute to the wider literature on rural sustainability as natural hazards challenge the viability of rural organisations and by extension, the social and economic sustainability of rural communities in developed countries [11, 14, 18, 138, 263, 264].

4.5 Rural organisational response to earthquakes

4.5.1 The Canterbury earthquake sequence

The Darfield earthquake occurred on a previously unknown fault structure in the Canterbury Plains later named the Greendale Fault structure [199] and initiated a series of over 4,000 aftershocks of M_w 3.0 or greater, with three equal or greater than M_w 6.0 [205]. In the first 6 months following the Darfield earthquake, the vast majority of aftershocks were associated with the Greendale Fault structure which was located west of Christchurch in the Canterbury Plains region [265]. However as shown in Figure 4.1, following the 22 February 2011 aftershock that caused widespread devastation and loss of life to the city of Christchurch, aftershocks were more frequently located near Christchurch. The eastward progression of aftershocks decreased the frequency and intensity of aftershocks in the Canterbury Plains region and increased the occurrence of aftershock foci near the city of Christchurch. For short-term analyses of the organisation impacts resulting from the Canterbury earthquake sequence, see Kachali et al. [254], Stevenson et al. [259] and Appendix A for urban or multi-sectoral analyses, or Chapter 3 for rural-specific analysis.

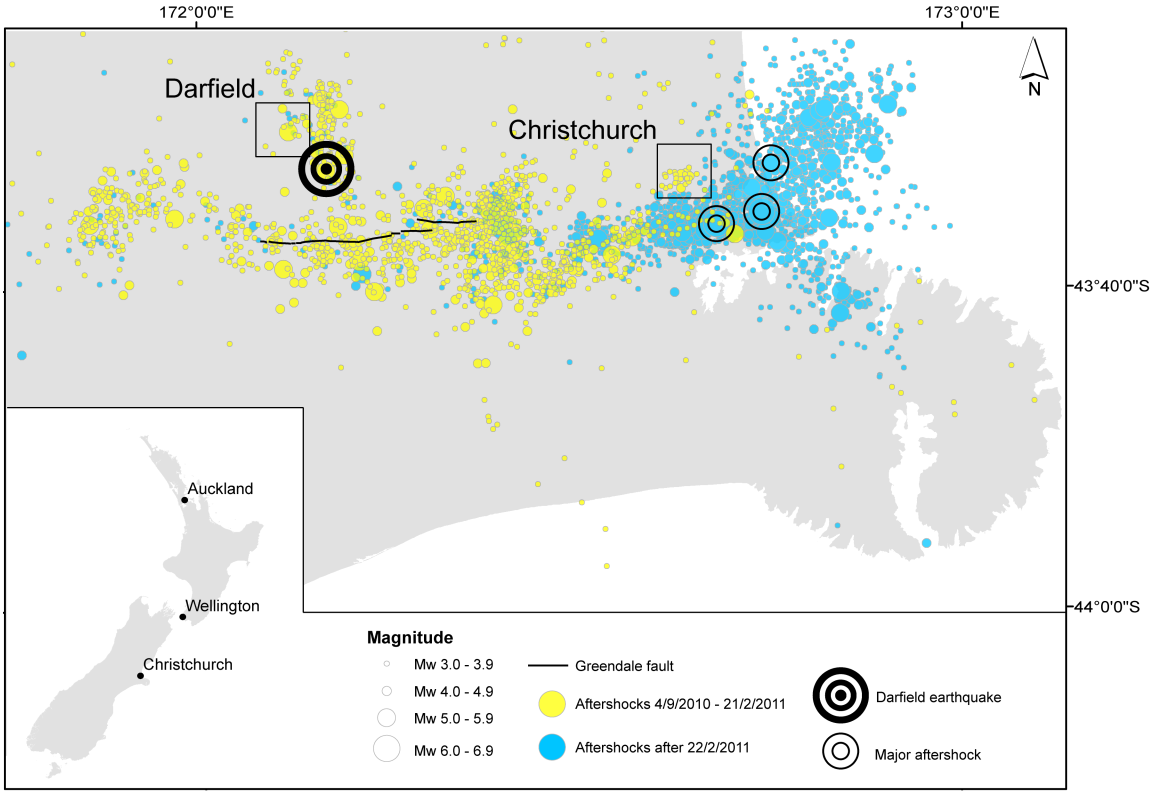

FIGURE 4.1: Map of the Canterbury earthquake sequence progression eastward, originating from the Canterbury Plains region towards Christchurch. Source: [265]

4.5.2 The organisations of the Canterbury Plains

Historically, farming was the Canterbury Plains first industry and is responsible for the early growth of the city of Christchurch, which served as a manufacturing centre for primary industry goods [266]. As the city has grown, farming has continued in the Canterbury Plains region as other industries have developed primarily in the city limits [266]. The most common type of organisation currently in the Canterbury Plains region are farming organisations, which represent 37% of all organisations. Although farming organisations are relatively small, commonly only 1 employee, farms employ more people than any other sector in the region. Other common industries in the region, which for the purposes of this chapter are categorized as rural non-farming organisations, are rental, hiring and real estate services (17%), construction (10%), and professional, scientific, and technical services (5%). The other sectors in the region consist of less than 5% of the total population of organisations [251].

In contextualizing farming organisations in New Zealand against farming organisations in other OECD countries, it should be noted that for all intents and purposes, farms in New Zealand receive no governmental subsidies. This is due to the neo-liberalization of New Zealand's economy which took place in the mid-1980s [267], and currently New Zealand farms receive the lowest levels of subsidization of any OECD country [161]. The lack of subsidization exposes these farms to higher levels of market volatility [163], which is often driven internationally because New Zealand's primary industries sell a significant percentage of total production overseas [208].

In terms of production infrastructure required in the region, the majority of farms in the region consist of fencing, grain silos, wells equipment sheds, and homesteads. Most farms in the region draw water locally and of all the regions in New Zealand, Canterbury farms have invested most heavily in irrigation, using rotary irrigators primarily [248]. There are some significant points of distinction for certain sectors. For example, the dairy sector requires higher levels of built infrastructure in the form of milking sheds and temperature-controlled milk storage tanks in order to maintain the herd sizes which are too large to milk by hand. Additionally, milking sheds and the storage tanks require electricity to operate. Generalizing production infrastructure required by the rural non-farming organisations in the Canterbury Plains is not tenable as the organisational sectors and types of operations included are highly variable.

4.5.3 Earthquake experience and preparedness

Rural communities in New Zealand have typically had to prepare and respond to biosecurity incursions and metrological hazards, such as flooding, storms and snowfalls. The absence of significant geophysical hazardous events in New Zealand made sustaining rural community awareness and preparedness challenging. However, prior to the Darfield earthquake, the potential for large, damaging earthquakes in New Zealand has been well recognized by New Zealand society. A series of damaging earthquakes in the early 20th century prompted the introduction of a number of earthquake risk reduction and readiness initiatives.

Extensive earthquake hazard assessment has identified major faults and led to the development of a probabilistic seismic hazard model, used primarily for building code development and land use planning. New Zealand adopted building codes to improve structural response to earthquake shaking in the mid-twentieth century and have periodically revised them to match new technologies and increasing societal expectations. Current codes rate structural resilience to the estimated effects of an earthquake based on the intended purpose of the building [268]. Buildings that are intended for critical infrastructure and habitation have the strictest guidelines, while buildings intended for stock or storage, classified as outbuildings, have lower requirements. Outbuildings are common infrastructure in a farming organisation, and possible, but not common attributes of rural non-farming organisations. Specifically for farming structures, New Zealand legislation includes earthquakes in the definition of physical conditions likely to affect the stability of buildings, building elements, and site work [268].

Critical infrastructure (lifelines) utilities also adopted integrated planning and seismic resilience projects. The Civil Defence and Emergency Management Act 2002 [249] requires lifeline utilities "to be able to function to the fullest possible extent", even though this may be at a reduced level, during and after an emergency. Regionally-based lifeline utility groups have been in place for up to 20 years working with scientists, engineers and emergency managers to identify interdependencies and vulnerabilities to regional scale emergencies. This collaborative process provides a framework to enable integration of asset management, risk management and emergency management across utilities. An example of this was in Canterbury where a multi-million dollar seismic upgrade of power networks took place in the late 1990s and throughout the 2000s in recognition of the seismic hazard.

A further earthquake risk transfer mechanism used by New Zealand is the central government backed natural disaster insurance for residential homes, land and contents, known as the Earthquake Commission (EQC). This manages a national disaster fund, funded through insurance levies and also promotes risk reduction and readiness activities.

Since the CDEM Act 2002, central and local governmental risk and emergency management agencies have attempted to use an approach of distributed accountability for hazard management, which acknowledges local communities are best placed to develop and foster community resilience to disasters rather than central authorities. These agencies also undertook sustained natural hazard (including earthquake) awareness and preparedness campaigns to encourage people to prepare for events [269]. However, the effectiveness of these programs showed limited levels of success as an earthquake preparedness study found that 51% of New Zealanders had taken no action to reduce or prevent damage as of April of 2010 [270]. This lack of preparedness has been attributed to the relatively long period quiescence, with over 70 years without a major urban earthquake, compounded with the relatively frequent exposure to small earthquakes [271].

4.5.4 Rural organisational planning strategies

The overall lack of preparedness for earthquakes was also observed for New Zealand organisations. In a survey conducted in Southland, New Zealand following the 2003 Fiordland earthquake, affected organisations were asked if they had performed any of the five following earthquake mitigating strategies prior to the event: (1) purchased extra insurance against earthquakes; (2) secured stock from falling; (3) secured heavy items; (4) bolted furniture to walls; (5) kept a 3-day supply of emergency survival goods such as water and food. The results showed that only 40% of affected organisations reported having carried out at least one of the earthquake preparedness measure. The low levels of organisational planning found by Forsyth and Johnston [175] is consistently found among small, rural organisations in different countries [130, 272]. Furthermore, affected businesses following the event did not show any significant increase in the development of planning strategies for future events [175].

However the lack of formalized planning strategies may not be an appropriate measure of preparedness. For example, following the 2006 Canterbury snowstorm, farmers attributed the concept of preparedness to personal experience and incorporating precautionary measures into their workflow or farm management practices [130]. Reasons for being ill-prepared for such an event included a lack of familiarity with the region, lacking prior experience with snow events, complacency, naivety, the cost of necessary preparations, and bad management [130]. One drawback of this perspective in the context of an earthquake event is that it relies on event recurrence intervals to be relatively short. In the case of a major earthquake affecting the Canterbury region, there are no instances that would allow for prior experience and consequently all regional farms would be not be defined as prepared.

4.5.5 Adaptive responses

As rural organisations illustrate relatively low levels of planning, the onus of recovery is largely placed on the organisation's ability to adapt to the effects of an event. Following an earthquake, organisations are likely to sustain some degree of damage to property or structures, non-structural damage, and critical service disruptions [273]. The impact these effects have on the means of production or the ability to operate in the post-disaster environment can have significant economic impacts for the organisation [3]. The amount of structural damage an area experiences is a factor in terms of an organisation's ability to continue operations, which is true even if the organisation's premises does not directly incur physical damage [109].

In mitigating the effects of an earthquake, back-up alternatives to lifelines help maintain levels of functionality in post-earthquake environments [220]. To mitigate the effect of earthquake asset damage or losses, Kunreuther [274] argues that insuring organisational assets is effective, and that populations with higher perceived risk of a major earthquake are more likely to take out insurance policies with higher levels of coverage. In terms of financing the recovery, organisations in good financial health prior to the event have been found to be more likely to have capital available to repair disaster-related damage, and consequently were more effective in a post-earthquake environment [173].

Accessing and maximizing resources such as available capital, social capital and alternative locations quickly are techniques found to be helpful in maintain or restoring operations in a post-earthquake setting [110, 173, 275] as well as in an biological epidemic. Phillipson et al. [276] observed that during the 2001 Foot and Mouth Disease epidemic, rural micro-firms utilized a wide breadth of coping response patterns, with the central theme of cutting costs wherever possible. The adaptive responses common to all businesses sampled were that household members worked longer hours, the owner operator took a lower wage, investments were either cancelled or postponed, and staff working hours were reduced. The use of these responses depended on a variety of factors specific to organisation, such as physical location, the level of fixed costs, or the number of full-time equivalent (FTE). For example, firms with more than one FTE (excluding the owner operator) were more likely to reduce staff working hours or refrain from taking on temporary staff, and extend the hours of employed family members. Smaller firms, lacking the ability to raise available capital through decreased payroll costs, used organisational savings and cut household spending. As the impacts continued over 8 months, the firms were likely to renegotiate existing loans or take out a new loan, and increase marketing [276].

4.5.6 The role of social capital in a rural post-disaster context

Another source of adaptive recovery often cited in the rural sustainability literature is the use of social capital. Social capital is a term that has been widely used in a variety of contexts, and consequently suffers from conceptual polysemy. For the purposes of this study, social capital is defined as the informal networked relationships built on norms of trust and reciprocity [277]. Social capital has been long understood to be a mechanism for community and organisational adaptation in both static as well as post-disaster contexts [81, 278, 279]. The informal ties and relationships garnered by organisations are cited as reducing costs and facilitating resource and information exchanges [278].

Social capital has been demonstrated to be relevant in shaping community and organisational adaptive capacity [277], contribute to rural community resilience [280, 281], and rural business resilience [137], in a wide variety of post-disaster contexts. Following the Midwestern Great Flood of 1993 in the United States, communities that fostered and embraced its cultural and demographic diversity were more likely to assist one another in the event of a disaster, and consequently were more likely to survive [12]. In the aftermath of the Zhangbei-Shangyi earthquake sequence in China, communities with higher levels of community and social support were more capable in mitigating psychological effects of the event [282]. The community that had lower levels of social support suffered from higher rates of depression, somatization and anxiety, which are demonstrative of the psychosocial impacts an earthquake can have on a rural community [282].

The use of social capital as a means of accessing social support in the farming sector is important to consider following a natural disaster for several reasons. In general, farming is considered one of the most stressful occupations [283], and high stress levels increase the likelihood for on-the-job injuries [284]. Following natural disasters, the effects of stress have consistently been cited as one of the most significant challenges faced by farming organisations [12, 13, 150], which can lead to an increase in errors of omission that negatively affect organisational performance [285], and can have long-lasting impacts such as the inability to sleep [14]. In a study conducted in the United States that quantitatively assessed the significance of different stressors experienced by farmers, loss of crop to weather (drought, flood, hail, wind, etc.) and severe weather conditions ranked in the top 10 most stressful events or activities [286]. In the same study, it was identified that farmers found asking for assistance from their neighbour to be a stressful activity while being asked for assistance was ranked as less stressful than going on holiday or vacation and just more stressful than winning the lottery [286].

In addition to social support, social capital can also be a useful lens in understanding the adaptive potential of rural economies post-disaster. In New Zealand and Australia, there is evidence of economically integrated rural communities that are highly interdependent and reliant on each other's services [18, 158, 245], however this may be in contrast to some rural communities in the United States where farms were found to be more dependent on their communities than the communities were dependent on agriculture [287].

In New Zealand, Smith et al. [14] observed a shift away from the cohesive rural community, which may be in part due to the increased reliance of farms on farm-support organisations instead of neighbour support. For farmers commenting on the use of neighbours following a major flooding event in the North Island, the following response was typical:

> "There is no real community any more like our parents had. We don't rely on our neighbours like we used to. For example, if we run out of drench, we call someone to replace it or go to town, instead of asking our neighbour."
>
> - pp. 546 [14]

This type of response may reflect an overall decrease in the sense of community in rural areas of New Zealand. However, Smith et al. [14] also observed that a flooding event appeared to have rekindled the sense of community spirit, citing examples of neighbour cooperation, and increased feelings of community appreciation. This result is a typical response in a post-disaster setting where community ties strengthen in response to the shared challenges brought on by a natural hazard [263, 288, 289]. That said, the effectiveness of community support was not evenly distributed, with community members with the stronger social networks able to access more assistance and citing the most positive views of aid provided. No evidence of corruption was cited by Smith et al. [14]; however the fact that assistance was not evenly distributed reflects the views of Rubio [290], who posits the danger of viewing social capital as solely a source of social good.

4.6 Research design

This study sampled organisations located in the Canterbury Plains. Organisations were broadly classified into two samples for the purposes of this study: farming and rural non-farming organisations. To determine the organisation's classification, the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 was used, with 'primary industry' subset as 'farming organisations'. The farming industry sectors included dairy, sheep and beef, arable, mixed, and less common livestock farming operations such as deer, llama or horse. All other organisations that did not fall under 'primary industry' were broadly classified as rural non-farming organisations. These organisations were primarily located in small rural towns such as Darfield, where agricultural represents a significant percentage of total industry in the region [247].

To capture the response and recovery to the Canterbury earthquake sequence, two questionnaires were used: one that assessed organisations immediately following the Darfield earthquake and a second in approximately one year later. The first survey (Survey 1 which can be found in Appendix C) was deployed to 304 organisations from October to December 2010 to assess the impacts, greatest challenges and methods of recovery. For a complete review of the methodology, see Chapter 3. The second survey (Survey 2 which can be found in Appendix C) was deployed to 78 organisations from April to June 2012. The 78 organisations were a subset of the original 304 which indicated they were willing to participate in future research. The second survey employed similar lines of questioning to the first questionnaire on mitigating strategies employed with a specific focus on the network relationships that were found helpful. Other items captured included the back-up alternatives used, the planning strategies developed prior to and following the Darfield earthquake, a general summary of impacts, the greatest challenges faced, and basic information regarding the organisation's supply chain.

Employing the total design method described by Dillman [192], several different mediums for response to the questionnaires were made available. Both questionnaires were first delivered to the organisation's physical address, and then followed up with a telephone call. Once the organisation was reached, they were presented with the opportunity to complete the questionnaire over the phone, returning the mailed copy in the pre-paid return envelope that was included in the original mailing, or completing the questionnaire using an online survey engine. Rural non-farming organisations were contacted between the hours of 10:00 and 16:00. Farming organisations were only contacted between the hours of 17:00 and 21:00 because it was more likely farmers would be near the phone.

All data collected from responding organisations was self-reported and therefore is subject to the bias of the respondents which could be affected by a variety of unknown factors. The limitations of self-reported data are well documented in the literature [18, 111], however there is no evidence to suggest the existence of a systematic bias in the dataset.

4.7 Results

In total, 25% of organisations sampled in Survey 1 (as described in Chapter 3) agreed to be contacted for future research. This yielded a sub-set of 78 organisations, of which 53% participated in the follow-up study. Overall, 41 organisations responded to both questionnaires. Farming organisations represented the majority (65%) of the sample. Of the farming organisations sampled, the majority (78%) kept livestock. The most common farm type was mixed livestock (32%), which typically involves a combination of sheep and beef stock complemented by some cropping either used as feed locally or intended for market. The second most common type of farm was dairy farming (12%), along with crop farming. The remainder of the sample fell equally (7% each) into three categories: arable, lifestyle, and other. The arable farming sector focuses solely on crop intended for market. Lifestyle farms, or hobby farms, are generally part-time arrangements where the farmer holds a full-time position external to the farm. These farms are not intended to turn a profit. Finally, an "other" category was designated for farms that specialise in less common livestock, including horse, alpaca, and deer. Farms employed on average 2 full-time and 1 part-time employees. The sector diversity is similar to that found generally in the region [247]. The number of employees per organisation was consistent across the farming sample despite the different farm-types. The average value of farming organisational holdings sampled was $7 million (NZD) which again was consistent across the farming sample. The average area of farms sampled was 250 hectares, with 93% of farmers reporting owning the land used for production. Farms, on average, maintained 8 farm buildings and their homestead.

Rural non-farming organisations comprised 34% of the sample and there was a large degree of sectoral variability within rural non-farming organisations. Retail organisations were the most common type of organisation, but comprised of only 7% of all non-farming organisations sampled. Manufacturing and agricultural contractors were the second most common, which consisted of 2 organisations in the non-farming sample. The remaining types of non-farming organisations included a utility service provider, a construction contractor, a hotel, a newspaper, a professional service consultant, a school, and an art gallery. The wide range of sectors is reflective of the regional breakdown of rural non-farming sectors [247], however the sample is not intended to be representative of all regional organisations.

Due to the sectoral diversity of the rural non-farming sector, there was a wide range in the number of full-time employees, the value of total organisational holdings (in NZD) and the number of buildings. The mean number of full time employees for non-farming organisations was 67, but with a high degree of variability (Std. Dev = 153). When the few very large organisations are removed, the average number of full-time employees decreases to 26 employees. Likewise, although some organisations included in the rural non-farming sample are valued over $100 million (NZD) with several buildings used in production, the more typical total value of the sample is nearer to $2 million (NZD) and with the use of a single building.

Comparing the farming and rural non-farming samples, farming organisations, on average, employed fewer staff than rural non-farming organisations and were more likely to be family-run organisations, operated by husband and wife partnerships, or sole ownership with no employees. Employees of farming organisations were much more likely to live on location and the homestead was often included in the farm's building assets. Farming organisations tended to be much larger in area than rural non-farming organisations and in most instances, maintained more buildings and had higher net worth (value of holdings).

A majority of both farming (74%) and rural non-farming organisations (93%) reported being affected by the effects of the 4 September 2010 Darfield earthquake. The direct impacts of the event forced 75% of rural non-farming organisations to close. As farming organisations do not close in the same sense, a much lower rate of closure (16%) was observed in the farming sample. With regards to the major aftershocks after the 4 September event, rural non-farming organisations were more likely to be affected, with over 71% reporting being affected by the 22 February 2011 aftershock. In contrast, just under half (41%) of farming organisations reported having been affected. All major subsequent aftershocks (13 June and 23 December 2011 events) affected less than 30% of both farming and rural non-farming organisations.

4.7.1 Supply Chain

With regards to supply chain, farming organisations showed a heavy reliance on local or regional suppliers. Nearly all (95%) farming organisations reported buying key inputs from suppliers that were locally based. Under half (45%) report purchasing key inputs from regional suppliers, and 27% purchase from suppliers based elsewhere in New Zealand. In selling goods, most farms (73%) reported selling to an agent, most (59%) also sell goods to a national co-op. Importantly, the majority of agricultural goods produced in New Zealand are exported to foreign markets [208]. In all cases, goods were picked up on site by an agent, co-op, or customer.

Rural non-farming organisations showed a markedly different supply-chain process. Most rural non-farming organisations sampled purchased from regional (85%) and local suppliers (70%). Sixty-two percent purchased key inputs from suppliers in New Zealand outside of Canterbury. Ninety percent of the customers of rural non-farming organisations were local. All sold goods directly to customers while 40% sold goods that were delivered via a third-party organisation, while the remainder was delivered at the point of sale.

The large majority of both farming and non-farming organisations cited either purchasing or selling goods locally. Farming organisations reported purchasing from local suppliers while primarily selling goods destined for the international market while the majority of rural non-farming organisations sold goods to locally based customers while purchasing from regional or national suppliers. In one example, a rural non-farming organisation summarized the overall impact of both the 4 September Darfield earthquake and the 22 February aftershock was that farmers stopped spending on non-essential items. These results support the findings of Phillipson et al. [276] where decreases in rural micro-firm spending is employed as a short-term response to a natural hazard, and illustrates that the decreased farm spending negatively affect the rural non-farming organisations, which was also observed in rural communities in the neo-liberal economies of New Zealand [158] and Australia [18, 245], but may conflict with some results in the United States [287].

4.7.2 Levels of preparedness

Despite experiencing the Canterbury earthquake sequence, there are still generally low levels of formalized emergency planning strategies in place for both farming and rural non-farming organisations sampled. Farming organisations rarely practised how they would respond to an emergency prior to the 4 September earthquake or afterwards. A greater proportion of the rural non-farming sample reported practising emergency responses, however only 1 in 10 had plans and rehearsed them prior to and following the 4 September earthquake. There was no evidence that the Canterbury earthquake sequence has prompted organisations to practice responses to emergencies which is similar to the response of Te Anau and Manapouri businesses in New Zealand following the 2003 Fiordland earthquake [175]. A summary table of these results collected from Survey 2 can be found in Table 4.1.

The majority of farming organisations indicated having back-up alternatives to water (63%), communications (63%), electricity (67%), and transport (56%). Electrical generators were especially helpful in the dairy sector as the means of production (milking) and storage requires electrical services. While generators were helpful, their reliability was problematic without proper maintenance. In one instance, the generator failed due to a lack of use and a working replacement could not be found.

The majority of rural non-farming organisations reported having back-up alternatives to water (71%), communications (64%), and electricity (57%). In comparison to farming organisations, rural non-farming organisations were much less likely to have back-up alternative means of transportation and natural gas. Overall however, rural non-farming

Table 4.1: Summary of emergency management plans and the rate of practiced responses to emergencies before and after the 4 September earthquake.

Sample	Question Item	Response	N	%
Farm	Do you have plans for how you would manage an emergency or natural hazard?	Yes	8	29.6
		No	15	55.6
		Missing	4	14.8
	Had/has your organisation practiced how it would respond to an emergency prior to 4 September?	Yes	3	11.1
		No	20	74.1
		Missing	4	14.8
	Had/has your organisation practiced how it would respond to an emergency since 4 September?	Yes	4	14.8
		No	18	66.7
		Missing	5	18.5
Non-farm	Do you have plans for how you would manage an emergency or natural hazard?	Yes	3	21.4
		No	10	71.4
		Missing	1	7.1
	Had/has your organisation practiced how it would respond to an emergency prior to 4 September?	Yes	6	42.9
		No	7	50
		Missing	1	7.1
	Had/has your organisation practiced how it would respond to an emergency since 4 September?	Yes	6	42.9
		No	4	28.6
		Missing	4	28.6

Table 4.2: Frequency and percentage of farming and rural non-farming organisational back-up alternatives to lifelines (critical services)

	Farm (N=27)		Non-farm (N=14)	
Backup Alternative	N	%	N	%
Water	17	63%	10	71%
Communications	17	63%	9	64%
Information Technology	8	30%	6	43%
Electricity	18	67%	8	57%
Transport	15	56%	4	29%
Sewerage	12	44%	6	43%
Gas	11	41%	4	29%

organisations showed relatively similar likelihood in having back-up alternatives to critical services when compared to the farming sample. No significant correlation was found between backup alternatives to the total number of days closed for non-farming organisations. A complete summary of the back-up alternatives maintained by both farming and rural non-farming organisations may be found in Table 4.2.

There were relatively high levels of confidence from both farming and rural non-farming

Table 4.3: The levels of confidence regarding the back-up alternatives held by farming and rural non-farming organisations. The abbreviation MV denotes missing values.

Sample	We have done sufficient planning for the following	≥Agree N (%)	≤Disagree N (%)	N/A N (%)	MV N (%)
Farm	Water	18 (67%)	2 (7%)	2 (7%)	5 (19%)
	Communications	15 (56%)	6 (22%)	2 (7%)	4 (15%)
	Electricity	17 (63%)	4 (15%)	1 (4%)	5 (19%)
	Transport networks	16 (59%)	5 (19%)	2 (7%)	4 (15%)
	Sewage	12 (44%)	6 (22%)	4 (15%)	5 (19%)
	IT	8 (30%)	7 (26%)	7 (26%)	5 (19%)
	Gas	7 (26%)	4 (15%)	10 (37%)	6 (22%)
Non-Farm	Water	10 (71%)	1 (7%)	2 (14%)	1 (7%)
	Communications	11 (79%)	1 (7%)	1(7%)	1(7%)
	Electricity	10 (71%)	3 (21%)	0 (0%)	1 (7%)
	Transport networks	8 (57%)	2 (14%)	3 (21%)	1 (7%)
	Sewage	8 (57%)	2 (14%)	3 (21%)	1 (7%)
	IT	8 (57%)	2 (14%)	2 (14%)	2 (14%)
	Gas	5 (36%)	2 (14%)	5 (36%)	2 (14%)

organisations with regards to the sufficiency of planning for the disruption to different types of critical infrastructure. For both types of organisations, the majority of organisations reported having sufficiently planned for all back-up alternatives, with the exception of natural gas for rural non-farming and sewerage, information technology (IT) and natural gas for farming. In comparing the two groups, the farming organisations were more pessimistic regarding their plans for back-up alternatives, and also more likely to omit the question. It was common for both farming as well as rural non-farming organisations to view back-up alternatives natural gas as inapplicable for their business. Farming organisations also were likely to see back-ups to IT as inapplicable as well. A complete summary of the organisational confidence levels regarding their back-up planning strategies may be found in Table 4.3.

For both farming and rural non-farming organisations, despite the awareness of the potential for a large earthquake due to semi-regular media publications [291–293] and the limited experience of earthquakes from small, localized events or larger, distant earthquakes, the overall levels of planning for an earthquake event were low, and the practised responses to the effects of an earthquake were essentially absent. Only the very large rural non-farming organisations maintained emergency planning strategies prior to the event, and reported having routinely exercised these plans. The experience of the Canterbury earthquake sequence did not significantly spur small rural organisations to create any type of emergency response plans, and of those that did, the plans were very informal. This lack of preparation to the earthquake hazard in New Zealand was supportive of the findings of Mayo and Newman [270] and Forsyth and Johnston [175], extending their findings from individual levels of preparedness to also include small, rural organisations.

4.7.3 Greatest challenges

The greatest challenges for farming organisations changed between the two surveys. Immediately following the event in 2010, the most commonly cited greatest challenges were stress (12%), structural damage (9%), maintaining production levels (9%), and ground damage (9%). There was a wide range of reported challenges in the first survey and consequently the most commonly cited challenges only represented 39% of all responses. Eighteen percent reported no significant challenges, which represents the single most common response for the "Greatest Challenge" item from farming organisations in Survey 1.

Sampled again in 2012, the greatest challenges for farming organisations were stress (21%), rebuilding or repairing structures (16%), staff well-being (13%), recovery agencies (11%) and increased workload (8%). While in both surveys, stress was the most commonly cited greatest challenge, the frequency of reports of stress doubled. Furthermore, staff-wellbeing – which was highly strongly related to staff stress levels also increased significantly, from 3% in Survey 1 to 13% in Survey 2. Both the challenge of rebuilding and the challenge of dealing with recovery agencies also increased between the two surveys, from 6% to 16% and 0% to 11% respectively. In the majority of cases regarding recovery agencies, the challenges were referencing inefficiencies in dealing with New Zealand's governmental insurance program (EQC) or the contractors assigned by EQC to make repairs. The largest decrease in greatest challenge frequency was observed in responses of no challenges, which decreased from 18% to 5%. A complete summary of greatest challenges for farming organisations is shown in Table 4.4.

For rural non-farming organisations, the greatest challenges reported between the two surveys were similar to farming organisations in that there were several different greatest challenges reported in Survey 1 and higher clustering around fewer challenges in Survey 2. In Survey 1, all challenges reported had only 1 or 2 instances, and therefore no trends

Table 4.4: Summary table of farming organisations' greatest challenges. The responses in Survey 1 (S1) are compared to those of Survey 2 (S2), and the change is responses are recorded as the Difference. Only those organisations that responded to both were compared, and the reason for differing N values is due to the option for organisations to report more than one greatest challenge.

	S1 (N=33)		S2 (N=38)		S1+S2 (N=71)		Difference	
Challenge	N	%	N	%	N	%	ΔN	Δ%
No Issues	6	18%	2	5%	8	11%	-4	-13%
Damage	3	9%	1	3%	4	6%	-2	-6%
Ground Damage	3	9%	1	3%	4	6%	-2	-6%
Production	3	9%	1	3%	4	6%	-2	-6%
Access to Premises	2	6%	0	0%	2	3%	-2	-6%
Uncertainty	2	6%	0	0%	2	3%	-2	-6%
Electricity	1	3%	0	0%	1	1%	-1	-3%
Weather	1	3%	0	0%	1	1%	-1	-3%
Family Issues	2	6%	1	3%	3	4%	-1	-3%
Stock Issues	2	6%	1	3%	3	4%	-1	-3%
Water Supply	1	3%	1	3%	2	3%	0	0%
Aftershocks	0	0%	1	3%	1	1%	1	3%
Supply Issues	0	0%	1	3%	1	1%	1	3%
Growth/Forecasting/Planning	0	0%	2	5%	2	3%	2	5%
Increased Workload/Demands	0	0%	3	8%	3	4%	3	8%
Recovery agencies	0	0%	4	11%	4	6%	4	11%
Staff Well-being	1	3%	5	13%	6	8%	4	10%
Rebuild	2	6%	6	16%	8	11%	4	10%
Stress	4	12%	8	21%	12	17%	4	9%

could be observed. Some of these challenges reported included the effects of aftershocks (9%), customer issues (9%), increased workload (9%), rebuilding challenges (9%), dealing with recovery agencies (9%), and supply issues. In Survey 2 however, organisations most commonly reported stress (17%) to be the greatest challenge, which incidentally was also the challenge with the largest increase of 12%. Three other challenges were equally reported at 13%: staff well-being, supply issues, and customer issues. Staff well-being was the second largest increase, from 5% to 13%. A complete summary of all rural non-farming greatest challenges can be found in Table 4.5.

For farming organisations, the frequency of reporting no major issues substantially decreased over time. This trend may indicate that although no major impacts were immediately perceived, as the aftershock sequence continued over time, major challenges emerged, largely in the form of stress and staff well-being which increased the most significantly between the two surveys. For both the farming and rural non-farming samples, stress and staff well-being were two of the most frequently cited greatest challenges that

Table 4.5: Summary table of rural non-farming organisations' greatest challenges. The responses in Survey 1 (S1) are compared to those of Survey 2 (S2), and the change is responses are recorded as the Difference. Only those organisations that responded to both were compared, and the reason for differing N values is due to the option for organisations to report more than one greatest challenge.

	S1 (N=22)		S2 (N=30)		S1+S2 (N=52)		Difference	
Challenge	N	%	N	%	N	%	ΔN	Δ%
Access to Premises	1	5%	0	0%	1	2%	-1	-5%
Aftershocks	2	9%	1	3%	3	6%	-1	-6%
Damage	1	5%	0	0%	1	2%	-1	-5%
No Issues	1	5%	0	0%	1	2%	-1	-5%
Recovery agencies	2	9%	1	3%	3	6%	-1	-6%
Stock Issues	1	5%	0	0%	1	2%	-1	-5%
Increased Workload/Demands	2	9%	2	7%	4	8%	0	-2%
Organisational Staffing	1	5%	1	3%	2	4%	0	-1%
Production	1	5%	1	3%	2	4%	0	-1%
Uncertainty	1	5%	1	3%	2	4%	0	-1%
Family Issues	0	0%	1	3%	1	2%	1	3%
Finance Issues	1	5%	2	7%	3	6%	1	2%
Rebuild	2	9%	3	10%	5	10%	1	1%
Customer Issues	2	9%	4	13%	6	12%	2	4%
Supply Issues	2	9%	4	13%	6	12%	2	4%
Staff Well-being	1	5%	4	13%	5	10%	3	9%
Stress	1	5%	5	17%	6	12%	4	12%

increased in frequency over time. The prevalence of stress and the effects of aftershocks on stress levels concurs with the disaster literature, and adds to the large body of work that has identified stress to be one of the most significant challenges faced for farming organisations [12, 13, 150].

For both farming and rural non-farming organisations, the effect of stress was strongly associated with the frequency and intensity of the very localized and shallow aftershocks. The shaking was found to disrupt sleep, and increase levels of anxiety, which is similar to the results of Smith [14] and Wang et al. [282]. For rural non-farming organisations specifically, there was a significant number of reported cases of stress being induced by speaking with customers about the earthquakes. This was especially noticeable following the Christchurch earthquake when Christchurch residents were displaced into the surrounding communities and retail organisations were frequently discussing the event with victims.

4.7.4 Mitigating factors

Immediately following the event, the majority of farms found insurance (85%), their neighbours (70%), well-built buildings (60%), emergency kits (55%), and backup alternatives to lifelines or critical services (50%) to be helpful in mitigating the physical, psychosocial, and economic effects of the earthquake. The three most common types of insurance held by farming organisations was property and buildings, organisation assets and equipment, and cash flow, income protection and organisation interruption. Of those farms that reported being affected, nearly all (89%) placed a claim for insurable losses following the Darfield earthquake. Insurable claims were made for chimney damage, silo damage, dairy shed structural damage, foundation cracking, water and septic tank damage as well as various non-structural losses. In terms of the level of satisfaction with their insurance, 68% of farms were very satisfied, 21% were satisfied, and 11% had neutral feelings. There were no instances of negative sentiment towards insurers. This is a somewhat surprising result as previously in the questionnaire respondents cited some challenges of dealing with insurers and we can only speculate that dealing with the insurers may have been a time and energy intensive process but ultimately, the result of the insurer support proved to be positive.

For farming organisations, neighbours were identified as providing two types of support: psychosocial support as well as providing additional labour when needed. From qualitative descriptions of the neighbours support, instances of emotional support were represented in 55% of recorded cases, while the remainder focused on labour assistance. Examples of emotional and labour support are as follows:

Emotional:

- “Spent a lot of time comforting neighbour. Any large rattle or noise from earthquakes got neighbour anxious. Last 6 months has generally been good.”
- “We have each other over for a cupa’ (slang for cup of tea) and just talk it through.”
- “I started a once a month gathering at our local winery, which is still going today and we all look forward to it, it has been a great way of getting to know the neighbourhood and who lives in it. We are all very supportive of each other.”

Labour:

- "Provided hands on deck for dairy farmer who needed a hand with getting water supply going for his cow shed."
- "Initial physical help to weatherproof home."
- "Some friends/neighbours came to help in the week after the EQ but it is difficult for them to understand exactly what was required. In these situations, as the person in charge, you are the only one who has the knowledge to prioritise and organise things. Although they try to help, they don't always know how things are done and it isn't necessarily much help in the end."

Emotional support was cited as most necessary as a direct result of shaking and therefore employed throughout the earthquake sequence. In contrast, the labour support was most necessary immediately following the event when the farm infrastructure sustained damage. Generally, the support was positively received and reciprocated. However in some cases, labour support was not viewed as effective because the farmer was required to actively manage the neighbours to ensure the work was being done properly. The gesture of support was appreciated but in practice, was viewed as a net drain on resources.

The majority of rural non-farming organisations utilized backup alternatives to lifelines (85%), relationship with staff (62%), well-built buildings (62%), and spare resources (54%). Just under half of rural non-farming organisations cited their neighbours as a helpful factor in mitigating the effects of the earthquake. When asked to describe the support received from neighbours, 78% reported being supported or reassured, especially following aftershocks. An example of this support reads as follows: "We checked on neighbours after each of the earthquakes and in turn they have checked on us". The remainder of cases involved neighbours helping to remove chimneys or clean up premises. A complete summary of mitigating factors can be found in Table 4.6.

Social networks were employed across both farming and rural non-farming organisations. However, farming organisations were more likely to rely on neighbour relationships while rural non-farming organisations were more likely to rely on their relationships with staff and suppliers. The use of these relationships evolved over time. Farming organisational use of neighbour relationships remained consistently high in both Survey 1 and Survey 2. In contrast, rural non-farming organisations cited staff relationships as helpful in 72% of cases in Survey 1 but only 15% in Survey 2. For rural non-farming organisations, the

Table 4.6: Summary table of factors identified as helpful in mitigating the effects of the earthquake. No data exists for back-up critical services in Survey 1 because the question was originally asked as an individual open-ended item that was not directly comparable.

	Farm			Non-farm		
	S1 (N=41)	S2 (N=20)	Diff.	S1 (N=19)	S2 (N=13)	Diff.
Mitigating Factor	%	%	Δ%	%	%	Δ%
Backup Critical Services	-	50%	-	-	85%	-
Emergency kit	49%	55%	6%	33%	8%	-25%
Insurance	71%	85%	14%	32%	46%	14%
Planned disaster response	20%	30%	10%	11%	38%	27%
Bank relationship	29%	45%	16%	17%	46%	29%
Neighbour relationship	71%	70%	-1%	33%	62%	29%
Staff relationships	34%	40%	6%	72%	15%	-57%
Supplier relationship	29%	25%	-4%	68%	46%	-22%
Different site	15%	10%	-5%	25%	8%	-17%
Available cash or credit	41%	40%	-1%	53%	46%	-7%
Spare resources	39%	40%	1%	56%	54%	-2%
Well-built buildings	76%	60%	-16%	17%	62%	45%

use of neighbours as a mitigating strategy increased from Survey 1 to Survey 2 because the neighbour support was cited as being helpful for personal reasons in decreasing stress levels brought about by the aftershocks and was not used to directly assist the organisation. For organisational assistance purposes, rural non-farming organisations used their relationships with their staff and suppliers. These measures likely decreased because as the higher intensity aftershocks decreased as they migrated eastwards towards Christchurch and removed the need to respond to the direct effects of the earthquakes, such as repairing non-structural damage and sourcing replacement stock.

4.7.5 Means of financing recovery

The most common means of recovery used by both farming and rural non-farming organisations was organisational cash flow. Rural non-farming organisations most especially relied on sources of available capital such as cash flow and organisational savings which is consistent with the findings of Dahlhamer and Tierney [173] who assert having available capital available immediately following an earthquake assists in the recovery process. For farming organisations, the majority (56%) also utilized their insurance claim as a means to financing recovery, which supports the findings of Kunreuther [274]. In contrast, only 27% of rural non-farming organisations used insurance as a means of recover,

Table 4.7: Means of financing organisational recovery broken down by farming and rural non-farming organisations. N-F stands for Non-farming organisations.

	Survey 1				Survey 2				Difference			
	Farm		N-F		Farm		N-F		Farm		N-F	
	N	%	N	%	N	%	N	%	ΔN	Δ%	ΔN	Δ%
Cash Flow	3	23%	7	64%	11	69%	8	73%	8	46%	1	9%
Savings	2	15%	5	45%	4	25%	6	55%	2	10%	1	9%
Family/Friends	0	0%	1	9%	0	0%	0	0%	0	0%	-1	-9%
Bank Loan	0	0%	1	9%	2	13%	1	9%	2	13%	0	0%
Credit Cards	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Insurance	4	31%	4	36%	9	56%	3	27%	5	25%	-1	-9%
EQ Wage Sub.	0	0%	1	9%	0	0%	2	18%	0	0%	1	9%

preferring instead to rely on organisational savings. A full breakdown of the different types of recovery options used can be found in Table 4.7.

In both the short and long term, organisational cash flow was the most commonly used method of financing organisational recovery. Further, cash flow was more commonly employed as the earthquakes persisted over time. Alternative sources of capital, such as money borrowed from family and friends, credit cards and bank loans were used occasionally, which suggest that these organisations had relatively healthy capital reserves at the time of the event and were not forced to source finances outside of the organisation. The use of insurance payments increased over time for farming organisations but decreased for rural non-farming organisations. As Phillipson et al. [276] observed following the 2001 foot and mouth epidemic, bank loans proved to be a longer term solution to the challenges faced by farming organisations during the Canterbury earthquake sequence. The heavy reliance on available capital (such as cash flow and organisational savings) are also comparable to the results of Phillipson et al. [276], and suggests that despite the very different nature of the events, similar measures were used to finance organisational recovery.

4.7.6 Organisational performance

To understand how the earthquake impacted on organisations ability to function, organisation's were asked to rate their organisation's performance using a Likert-scale assessment from very poor to excellent beginning from 2008 through 2011. Organisations were then asked to explain any changes in performance that was observed. Farming organisational performance showed no overall decrease during the Canterbury earthquake sequence, as illustrated in Table 4.8. This is because the impacts of the earthquake sequence did not directly impact on-farm production, but rather damaged infrastructure and caused increased stress levels for farmers. In fact, organisational performance in 2010 and 2011 were markedly better than 2008 or 2009, which was entirely attributed to the strength of commodity prices. Therefore, commodity prices were better indicators of organisational performance than the level of impact sustained during the earthquake sequence.

Rural non-farming organisations also saw no significant change in organisational performance in 2010 and 2011. While generalizations across the rural non-farming sample group are not possible, retail organisations cited increased customer numbers resulting from reconstruction efforts as well as increased populations in certain circumstances due to residents of Christchurch relocating in the rural areas near the city. One farming organisation cited observing increases in rural populations due to displaced Christchurch residents and another farmer was approached by agents to sell their property for residential development purposes. For farming organisations, when asked about organisational performance, only one farm stated performance levels were below average following the 4 September earthquake. The drop in performance was attributed to market changes and not a result of the direct effects of the earthquake sequence. A complete summary table of organisational performance for both farming and rural non-farming samples may be found in Table 4.8.

4.7.7 Limitations

The purpose of this analysis was to compare the impacts of a major earthquake and aftershock sequence on farming and rural non-farming organisations. Due to the limited size of the sample set and self-selected nature in which responses were collected, these results are not intended to be regionally representative. The two broad categories act as a first-order analysis, and do not resolve differences that may exist between industry sectors and should be subject for future research. This is most apparent in the rural non-farming sector, and the effect of this broad inclusion of several disparate industry sectors was manifest in large degrees of variability across descriptive attributes. For

Table 4.8: Farming and rural non-farming organisational performance summary of 2007 to 2011. Organisational performance was assessed through a 5-point Likert-scale question where respondents were directed to rank performance from Poor to Excellent.

Sample		Poor		Below Ave.		Ave.		Above Ave.		Excellent	
	Year	N	%	N	%	N	%	N	%	N	%
Farm	2007	0	0%	4	18%	9	41%	8	36%	1	5%
	2008	0	0%	2	9%	11	50%	9	40%	0	0%
	2009	1	5%	1	5%	10	45%	10	45%	0	0%
	2010	0	0%	0	0%	6	27%	16	73%	0	0%
	2011	0	0%	1	4%	6	27%	14	64%	1	5%
Non Farm	2007	1	13%	0	0%	2	25%	4	50%	1	13%
	2008	0	0%	0	0%	3	38%	4	50%	1	13%
	2009	0	0%	0	0%	2	25%	6	75%	0	0%
	2010	0	0%	0	0%	1	13%	6	75%	1	13%
	2011	0	0%	0	0%	1	13%	5	63%	2	25%

the farming sample, the arable farming sector is underrepresented and therefore further research is required with a regionally representative sample of industry sectors. While these limitations mean that the conclusions should not be generalized across different contexts, the research extends the conversation of rural resilience to natural hazards by providing much needed empirical data regarding rural organisational responses to the effects of earthquakes and a protracted earthquake sequence.

4.8 Conclusions

The Canterbury earthquake sequence created an extended period of recovery for rural organisations which illustrated the varying mitigating strategies employed by farming organisations in contrast to rural non-farming organisations, and the evolution of these organisational adaptations to the changing effects of aftershocks. The data have shown that rural organisations relied heavily on informal networked relationships in response to and throughout the Canterbury earthquake sequence, and that those relationships increased the resilience of affected organisations.

Although there were very low levels of formalized planning strategies prior to or following the Darfield earthquake, coping responses were employed quickly following the event demonstrating the efficacy of the organisations' ability to responsively adapt to external stressors. Immediately following the Darfield earthquake, the majority of organisations were capable of redirecting organisational savings and organisational cash flow to repair damages, and were not forced to redirect household funds with the exception of increased workloads. A flexible labour reserve was used to adapt to the increased workload that resulted from changes in the organisations customer base.

Organisations employed their informal relationships to assist in either repairing damages or in sourcing replacement stock, materials or goods. Labour support assisted in repairing structures and in sharing resources such as dairy sheds, which was most commonly employed immediately following the 4 September earthquake As the aftershocks continued, the effects the earthquakes began to affect the mental state of the organisational personnel. The adaptations to the aftershock sequence evolved, with a further reliance on informal networks as a means to decrease stress. The challenge of coping with the stress of the aftershock sequence increased over time to become the single most challenging aspect of the event and consequently recourse to psychosocial support through informal networks increased for both farming and rural non-farming organisations. Similar to the results of Smith et al. [14], sleeplessness and anxiety were the most commonly cited effects of consistently elevated stress levels.

Neighbours were used as the primary source of external psychosocial support, taking the form of calling in to check on one another or in the creation of regular meetings as a way to lower stress. These results suggest that psychosocial support is likely to be most needed during periods of aftershock activity, and are supportive of the findings of Wang et al. [282] regarding the use of community as a means to lessen the psychosocial impacts of the event.

Although the Canterbury earthquake sequence had wide-ranging implications for affected rural organisations, these impacts did not translate into decreased organisational performance. Trading did slow immediately following the Darfield earthquake both for farming organisations and local farm-support organisations, with any non-discretionary funding redirected for recovery purposes. However, the decrease in trading resumed to normal levels quickly and, for certain sectors, the earthquake sequence acted to draw additional customers to the region. The additional customers were the result of construction workers arriving in the region to make repairs, and residents of Christchurch who, prior to the 22 February event, came to view the damage to the region, and following, to escape the damaged city.

In summary, the chapter has shown the importance of social capital in the evolution of responses farming and rural non-farming organisations employed during the Canterbury earthquake sequence. For these rural organisations, informal networked relationships played an integral role in their adaptive capacities, both in the short and medium term. The chapter has also shown that during the earthquake sequence, stress has become the most significant challenge facing organisations, likely as a result of consistent exposure to aftershocks. Affected rural organisations appear to have been capable of absorbing the effects of the earthquake, but suffered psychosocial challenges as a result.

4.9 Acknowledgments

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Chapter 5

Farming and rural non-farming organisational impacts and repair costs following the Canterbury earthquake sequence

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5.1 Overview

The purpose of this chapter is to document the asset and flow costs incurred by farming and rural non-farming organisations during the Canterbury earthquake sequence. All financial data used in this chapter was collected from the "follow-up" questionnaire. These data are used to create a method of estimating the total asset repair costs for a future earthquake scenario. Finally, these data are compared to organisational performance metrics such as revenue and profitability to determine if these cost impacts had any effect on overall organisational performance.

The theoretical framing in this chapter draws from the engineering resilience tradition, with the use of the SUST vulnerability model, which views vulnerability as a constituent part of resilience. In the analysis of several organisations, which, when viewed as individual systems, a generalized model of individual system performance is established in the DRR tradition. The mention of resilience is attributable to the engineering resilience definition as explained in Chapter 1. In determining factors affecting systemic (the community of rural organisations) resilience, the SUST vulnerability model was employed, and techniques similar to Chang and Falit-Baiamonte [294] are used.

5.2 Contributions

Mr. Whitman designed the survey distribution methodology, conducted the data collection process, and performed the data analysis. The questionnaire was developed by Mr. Whitman, Mrs. Stevenson, and Ms. Kachali in collaboration. Dr. Wilson, Dr. Seville, and Dr. Vargo advised the questionnaire development process, the distribution design, and data analysis, as well as contributed comments and revisions to the manuscript.

5.3 Abstract

The Canterbury earthquake sequence (2010-2012) impacted the high-intensity agriculture region of central Canterbury in New Zealand's South island. A 29 km fault rupture, strong ground shaking from a series of earthquakes, and liquefaction ground damage impacted rural organisations in the region. This study presents the impact costs for rural

organisations, describes the damage states of organisational assets, the associated repair and disruption costs attributable to both asset and flow damages. The results presented here show that farming organisations experienced lower mean asset losses, despite suffering more serious asset damage, when compared to rural non-farming organisations. Also affected farming and rural non-farming organisations experienced no significant decrease in revenue following the earthquake sequence, exhibiting greater sensitivity to factors such as commodity prices or the local business environment. In addition, this study identifies that the Modified Mercalli Index (MMI) was best suited for impact scenario modelling for rural organisations and farming organisational loss modelling.

5.4 Introduction

On 4 September 2010 the central Canterbury Plains region of New Zealand was subjected to the M_w 7.1 Darfield earthquake and over 4,000 aftershocks of M_w 3 or greater for a period of two years [205]. This Canterbury earthquake sequence directly affected an area populated by farming and rural non-farming organisations located in or near small towns. These areas were strongly affected by severe ground shaking, a 29 km fault surface rupture, liquefaction, and flooding. This resulted in widespread building damage, losses of critical services or lifelines, and psychosocial effects to the population. As the first major earthquake disaster in New Zealand for over 70 years, very little was known regarding how rural organisations would respond to these impacts.

Although impacts to critical infrastructure and urban business are commonly studied following major earthquakes e.g. [3, 4, 7, 109, 111, 173, 212, 215, 295], to the best of our knowledge, there have been no studies that have catalogued the impact to farming or rural non-farming organisations, analysed the costs of damage to those assets, or the cost and time required in repairing the damages. This is somewhat surprising, given farming and rural non-farming organisations are important components of most nations economies and food security [30, 40, 208]. For this study, organisations that are classified as agriculture under the ANZSIC 2006 convention [209] are defined as farming organisations while organisations not included in the agriculture classification were defined as rural non-farming organisations.

This chapter summarizes the impacts of the Canterbury earthquake sequence on farming and rural non-farming organisations, and identifies metrics for rural organisational fragility functions as a means to estimate earthquake-related losses for future events. Specifically, the chapter: (1) provides empirical data regarding the direct and indirect impacts of the Canterbury earthquake sequence and organisational repair costs over the two years following the event. The repair costs include contents repair costs, clean-up costs, disruption costs, productive time lost, and building damage state repair cost estimates; (2) analyses the impacts of the earthquake sequence to organisational performance; (3) identifies metrics suitable for organisational fragility function development to aid in forecasting losses of future events; and (4) produces an overall loss function of farm organisational asset repair costs for the sampled population.

5.5 Literature review

This section (1) presents a brief overview of common observed earthquake impacts and losses for organisations from previous studies, and (2) outlines the development process of a fragility function for organisations.

From the disaster literature, several studies have identified the likely impacts earthquakes can have on organisations in general, as well as a variety of organisational attributes such as size, location, or industry sector that are useful predictors of the amount or type of damage sustained [4, 111, 210, 215, 295]. Overall, organisations will likely sustain some degree of direct physical damage to structures or property, non-structural damages, and critical service disruption during moderate to strong ground shaking [105, 172]. However the effect these impacts have on the organisation are controlled by a wide variety of factors including, but not limited to, the means of production or ability to operate in the post-disaster environment [220]. Because of this, damage patterns are often associated with industry sectors [3].

Smaller organisations are more likely to fail following an earthquake [215], which in some cases can be attributable to a lack of resources in the form of available capital [173], social capital [275], or alternative locations [110, 218]. The location of the organisation has also been identified as an important factor [109, 111], and revenue changes following an event show sector-specific patterns [6, 7, 109], as illustrated in Chapter 3, and Appendix A .

5.5.1 Earthquake-related costs

Measuring the costs of an earthquake for organisations has been a consistent challenge as there are currently no accepted standards for assessing financial impacts on organisations despite there being attempts to do so for comparative economic modelling purposes [112], and even if there were, different agencies and entities calculate costs and losses differently. The unit of analysis for organisational impact studies following earthquakes also vary. The most predominate type of study deals with the regional effects of an earthquake, with a limited subset of studies analysing impacts at the individual organisational level [296].

Studies that deal with the cost impacts of an earthquake on organisations predominately are used for regional modelling purposes [112, 297, 298]. In determining the cost-related effects an earthquake can have on an organisation, stocks and flows must both be considered [299]. Stocks are an asset quantity at a specific time while flows are the organisational output of stock over a given period [300]. Asset damages decrease stock value and may lead to decreased organisational output, however these two measures can act independently. For example, an organisation without any structural or non-structural damages may be interrupted due to critical service outages. Flow measures are considered more consistent with organisational health such as profitability, however empirical data for both stock and flow impacts to organisations following natural disasters are needed [299].

From the limited subset of studies that have gathered empirical data regarding organisation or business losses, Chang and Falit-Baiamonte [111] found in a survey of 107 businesses following the Nisqually earthquake in 2001, damage costs incurred by organisations varied significantly, ranging from \$62,000 to 1.2 M in stock losses and between \$2.5 M to 3.1 M in flow losses (all costs shown were reported in USD and adjusted for inflation for comparative purposes). Nearly all (80%) businesses financed losses through organisational savings, insurance or personal financing [111]. One significant finding from Chang and Falit-Baiamonte [111] was that a great diversity of losses can occur within a limited geographic region, with some organisations suffering greatly while nearby or neighbouring organisations escape physical damages. However, despite some organisations not incurring physical damages, these organisations did suffer from customer loss due to the physical damages to the local area [111].

Similar to Chang and Falit-Baiamonte [111], Tierney [109] found a wide range of dollar value losses following the Northridge earthquake in 1994. Adjusted for inflation, the median and mean dollar losses from physical damages were approximately $7,000 and $218,000 USD respectively. Approximately 40% of business sampled incurred structural damage and nearly 70% incurred some form of non-structural damages.

Despite immediate stock and flow costs, eight years following the 1989 Loma Prieta earthquake Webb et al. [6] found that affected businesses approximately sixteen kilometres from the epicentre in the Santa Cruz Mountains reported being the same or better off, both in terms of profitability and number of clients [6]. In this circumstance, the strongest predictor for improved performance was found to be the perception of business climate [6].

5.5.2 Earthquake loss estimation for rural organisations

One key purpose of assessing the costs of an earthquake on organisations is to provide empirical evidence to aid in forecasting losses of future events. Regional loss modelling initiatives such as HAZUS in the United States and Riskscape in New Zealand relate earthquake shaking intensity to property damage and business interruption losses to model the cost impacts. The HAZUS Earthquake methodology calculates direct economic losses to businesses as either capital related or income related costs [112]. Capital related losses include building repair or replacement costs and non-structural damage to assets. Income related costs include relocation and business interruption. Riskscape employs a similar methodology. Measures of asset repair costs, contents repair costs, and clean-up costs assess stock impacts while measures of disruption costs, revenue and profitability changes are used to assess flow impacts [301]. Both HAZUS and Riskscape calculate expected building damages using building fragility functions from which expected asset costs can be deduced. For example, the HAZUS model predicts that in the event of a M_w 7.8 earthquake in southern California, the overwhelming majority (94%) of agricultural buildings will experience no or moderate structural damage, and are assigned no structural asset costs [113].

Within performance-based earthquake engineering, fragility functions are used to forecast the likely outcomes of structural and non-structural assets when subjected to a given earthquake hazard intensity metric, such as the distance from the fault scarp, the Modified Mercalli Index (MMI), or the peak ground acceleration (PGA). The development of damage-analysis for organisations works under the same basic premise: identify useful impact parameters and analyse the effects of varying intensities on the unit of analysis [302]. There are four steps in the process: (1) describe what the fragility function will address; (2) detail the parameters of the event; (3) catalogue the damage evidence and define the damage measures; and (4) summarize the results, define the analysis method, and report the results [302].

There appear to have been few or no studies which considered an appropriate hazard intensity metric for fragility functions which assess loss to rural organisations. The Modified Mercalli Index (MMI) has been used in previous studies as a method to categorize the severity of an earthquake on organisations e.g. [109, 253], and regional impact modelling scenarios [112, 113, 303]. PGA is an objective measure of ground shaking intensities and is employed in earthquake engineering analyses [304], geophysical characterization of the earthquake [305] as well as in regional impact modelling scenarios [112].

5.6 The 4 September 2010 Darfield earthquake

The M_w 7.1 Darfield earthquake occurred on a previously unknown fault structure – later named the Greendale fault [199] – near the rural town of Darfield in the Canterbury Plains. Peak ground accelerations from the event were extreme, with measurements near source greater than 1g [200], exceeding building code standards in Christchurch, 45 km from the epicentre [202]. The event created a 26 km long surface rupture damaging intensive farm land, structures and the rural road network, with components of maximum lateral and vertical offsets of 5 meters and 1 meter respectively [199]. Liquefaction caused lateral spreading and differential settling which damaged building foundations and critical infrastructure [256, 257], while surface ejecta deposits buried pastures and crops in farm paddocks (fields) impacting production, if not incorporated or removed [129]. Electricity and water were disrupted for hundreds of thousands of residents in the Canterbury Plains and the city of Christchurch [201].

The Darfield earthquake triggered a sustained aftershock sequence in the region, with three M_w 6 or greater occurring in the next 18 months to the east. The majority of aftershocks that occurred before the 22 February 2011 were located mostly on or near the Greendale fault at a shallow depth causing further (sometimes strong) shaking for rural areas. The first major aftershock was the M_w 6.2 Christchurch earthquake on 22 February, 2011. The earthquake occurred directly under the city of Christchurch, causing substantially more severe and widespread damage than the Darfield earthquake; including 185 deaths and thousands of injuries [255]. After the Christchurch earthquake, aftershock activity shifted significantly eastwards from the Greendale fault to fault structures under or east of Christchurch city. The eastward progression of aftershocks, as illustrated in Figure 4.1, decreased the frequency and intensity of shaking in rural areas.

5.7 Regional organisations exposed to shaking

The most common type of organisation in the Canterbury Plains region are farms (comprising 37% of all organisations) and in total, employ more staff combined than any other industry sector [306]. The rural non-farming sectors in the region consist of rental, hiring and real estate services (17%), construction (10%), and professional, scientific and technical services (5%). The remaining sectors comprise less than 5% of all organisations in the region [306]. A summary of the sectors present in the Canterbury Plains region can be found in Table 5.1.

Farming infrastructure in the region is sub-sector dependant, but largely consists of a few common features: fencing, grain silos, wells, equipment sheds, and homesteads [267]. In the sectors that keep livestock, further structures are required. Dairy farming requires the greatest investment in built infrastructure with milking sheds for production, feed provision, and watering and irrigation requirements [233]. Most farms in the region draw and store water locally, and the use of rotary irrigators is common [248]. While all farms in the region require the use of electricity in some aspect of production, dairy farms require most to operate the milking shed and milk storage tanks [233]. The majority of dairy farms in New Zealand belong to national co-ops [167], which collect milk via tankers on a regular schedule.

Comparatively, rural non-farming organisations in the region are highly variable in sector and type of operations [306]. Generalizing across these different sectors is largely untenable, however the majority require a structure for operations, and rely on critical services such as electricity and water services as a means of production. These structures can range from a single household to a large manufacturing processing plant or campus. The majority of organisations in the region are small to medium in size and consequently the building requirements for operations are limited.

Under Schedule 2 of the 2004 Building Act, the building codes applicable to farms generally fall under three categories: housing, industrial and outbuildings. These three building types have different levels of required performance, with the most stringent requirements placed on housing [268]. Outbuildings have the least performance requirements and can be built to lower standards as they are not intended for human habitation [268]. For rural non-farming organisations, there exists a wide breadth of building types used. However most of the different structure types are rated to similar performance levels, with the exception of the outbuildings, which are less common for rural non-farming organisations but still possible organisational assets.

5.8 Methods

Organisations sampled in this study were located in the Canterbury Plains which is a rural area west of Christchurch, New Zealand, as shown in Figure 5.1. The sample was divided into two types of organisations for the purpose of this study: farming and rural non-farming organisations. Using the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 convention, organisations defined as primary industry were labelled farming organisations [209]. Farming industry sectors included dairy, sheep and beef, arable, and mixed among other less common sub-categories such as llama or deer farming. Organisations sampled that were not classified as primary industry sectors were broadly categorized as rural non-farming organisations. These organisations were located in small rural towns where the agricultural sector represents a significant percentage of total industry in the region [306].

The sampled population consisted of 76 rural organisations located in the Canterbury Plains that were respondents to an initial impact survey deployed in October-December

2010 immediately following the Darfield earthquake (see Chapter 3 and Appendix A for a complete review of the methodology). During the initial impact survey, respondents were asked if they would be willing to be contacted in the future regarding a second questionnaire. Those respondents that gave their consent were contacted with the questionnaire used in this study. Only organisations that participated in the initial impact survey and agreed to partake in future research were solicited to take part in the questionnaire used for this study. No data from the initial impact survey were included for analysis in this study.

The questionnaire used in this study was deployed from 18 April to 11 June 2012 to the 76 respondents previously mentioned (which can be found in Appendix C as the "Follow-up" questionnaire). A multi-media version of the total design method described by Dillman [192] was employed. Questionnaires were first delivered to the organisation's physical address, and then followed up with a telephone call. Once potential respondents were reached, they were presented with the option of completing the questionnaire over the phone, online via a survey engine, mailing back the hard copy with a prepaid envelope, or completing a soft-copy version and emailing their response. Rural non-farming organisations were contacted weekdays between 10 AM and 4 PM. Farming organisations were contacted by phone on weekdays between the hours of 5 PM and 9 PM when the farmers were more likely to be reached. The questionnaire was approved by the University of Canterbury Human Ethics Committee (approval code HEC 2011/30) prior to deployment. A copy of the questionnaire is available from the lead author.

The questionnaire included business demographic items such as organisational sector, whether the organisation owned or leased the property from which it operated, the number of employees, and location were items used to categorize respondents. It also contained quantitative measures of productive time loss, total value of organisational holdings (e.g. the total valuation of the organisation), as well as the reinstatement costs of the following items: (1) Asset Repairs, which are costs incurred in restoring, repairing, or replacing assets (Buildings, Silos, Livestock, Vehicles and other machinery, etc.) to their pre-event state; (2) Contents Repairs, which are costs incurred in returning the contents of the asset to their pre-exposure state; (3) Clean-up, which are costs incurred for necessary demolition, and/or removing debris, silt, effluent, etc.; and (4) Disruption, which are costs incurred due to the disruption of activities usually conducted. In addition, the respondent was asked to estimate the damage state of up to 5 buildings using the following 5 categories: (1) No damage, or minor non-structural damage; (2) Non-structural damage only; (3) Repairable structural damage; (4) Irreparable structural damage; and (5) Structural integrity fails. These items were based on the schema used by the RiskScape software modelling by GNS Science as a method to assess damage classes across multiple natural hazards [113, 303].

All data collected was self-reported, and collected following the event; the pre-existing state of the organisation is unknown. The perceived impact to the organisation is subject to the bias of the respondent, as some may under or over report organisational disruption levels based on external circumstances such as personal stress levels. Self-reported data has a certain potential for bias, which is well noted in the disaster literature [18, 111], however there is no evidence to suggest a significant bias, either positive or negative, exists in the dataset.

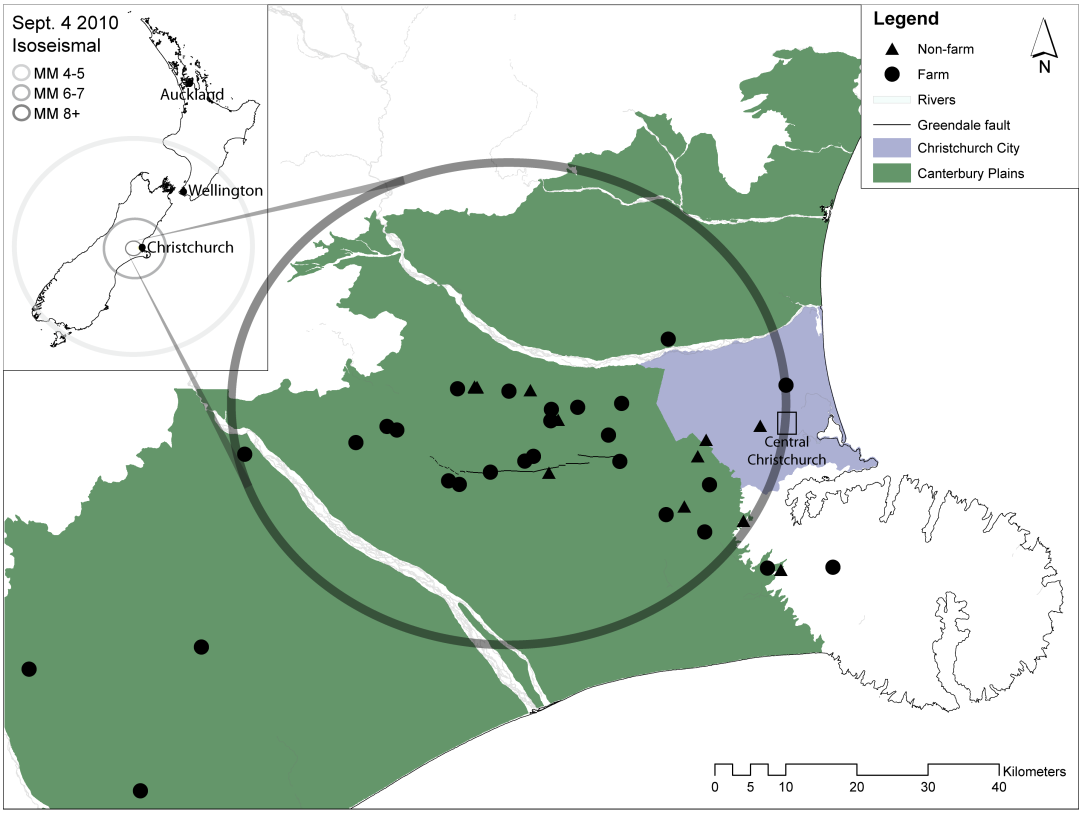

FIGURE 5.1: Location of responding farming and rural non-farming organisations. Points within the Canterbury City boundaries are not urbanized areas but fall within the political boundaries of the cit/.

Table 5.1: Breakdown of farming and rural non-farming groups by their industry sector classification.

Sample	Sector	N	Percent	Cant. Plains
Farming	Dairy farming	5	12%	20%
	Arable farming	3	7%	18%
	Mixed livestock farming	13	32%	42%
	Other	6	22%	20%
Rural non-farming	Agriculture (non-farm)	2	5%	<1%
	Manufacturing	2	5%	4%
	Electricity, Gas, Water and Waste Services	1	2%	<1%
	Construction	1	2%	10%
	Retail Trade	3	7%	4%
	Accommodation and Food Services	1	2%	2%
	Information Media and Telecommunications	1	2%	<1%
	Professional, Scientific and Technical Services	1	2%	5%
	Education and Training	1	2%	1%
	Arts and Recreation Services	1	20%	2%
Total	Farming Total	27	65%	38%
	Rural non-farming Total	14	34%	62%

5.9 Results

The objective of this section is to: (1) characterise the sampled organisations; (2) identify the impacts and reinstatement costs; (3) summarize the types of damage to organisational assets; (4) analyse the correlations between hazard intensity metrics and organisational impacts; (5) evaluate the impacts of the earthquake sequence on organisational performance; and (6) define cost estimation functions for farming organisations.

5.9.1 Organisational attributes

The response rates of 70% for rural non-farming organisations and 71% for farming organisations were attained. Overall, farming organisations represented the majority (65%) of the sample. A breakdown of the different types of farming organisational sectors can be found in Table 5.1. There was a large degree of sectoral variability of the rural non-farming organisations, with the most common sector (retail) representing only 7% of all non-farming organisations.

When compared to rural non-farming organisations, farming organisations reported lower numbers of all types of employees (full-time, part-time, and temporary) and lower

Table 5.2: Summary table of descriptive variables regarding farming and rural non-farming organisational sample groups.

Category	Variable	Farm (N=27)	Non-farm (N=14)
Attributes	Mean no. full-time staff	2 (Std Dev=3)	67 (Std Dev=153)
	Mean no. part-time staff	1 (Std Dev=1)	4 (Std Dev=59)
	Mean no. temp staff	0 (Std Dev=2)	0 (Std Dev=54)
	Area of organisation (ha)	253 (Std Dev=245)	7 (Std Dev=12)
	No. of buildings	9 (Std Dev=6)	21 (Std Dev=66)
	% Own	93%	64%
	Mean Holdings (NZD)	$ 6,960,000	$ 287,036,000
	St.Dev Holdings	$ 6,964,000	$ 755,348,000
	10% Trim mean Holdings	$ 5,809,000	$ 1,849,000
Affected	% Affected 4 Sept 2010	80%	93%
	% Affected 22 Feb 2011	46%	77%
	% Affected 13 June 2011	30%	33%
	% Affected 23 Dec 2011	26%	36%
Closure	% Closed 4 Sept 2010	16%	75%
	% Closed 22 Feb 2011	0%	17%

values of holdings. Farms occupied larger land areas, and in most cases used more buildings on site. The rural non-farming sample showed a broad range of number of full-time employees, value of total organisational holdings (in NZD) and number of buildings. For example, the standard deviation for full time employees for non-farming organisations was almost twice as large as the mean. Further examples of the wide range of rural non-farming organisational attributes may be found in Table 5.2. Farming organisations showed reasonably similar organisational attributes despite the different farming sub-sectors comprising the farming sample group. The farms were relatively similar in the number of employees, the amount of area farmed, the value of holdings, and number of buildings used in operations.

5.9.2 Damages and disruption

The majority of farming and rural non-farming organisations reported being affected by the Darfield earthquake, while the major aftershocks affected significantly fewer organisations. Rural non-farming organisations sampled were more likely to be affected by any earthquake, and were more likely to close temporarily. Although 3 farming organisations did report closing, farming organisation do not "close" in the same sense that retail or manufacturing organisations do, and consequently this metric is not directly applicable to the agriculture sectors. The majority (75%) of rural non-farming organisations were forced to close following the Darfield earthquake for an average of 4 days ($Std.Dev = 2.6$). The 22 February Christchurch earthquake forced 2 farming organisations (7%) and 4 rural non-farming organisations (29%) to close but they did not report the duration of closure. For rural non-farming organisations, 3 of the 4 closures were due to the need to clean up damage to the interior of their buildings. The remaining case did not report their reasons for closure.

No farming organisations reported making any staff redundant. For rural non-farming organisations, two (14%) reported making staff redundant due to families moving away from the area and a lack of work, respectively.

Respondents were asked to report the productive time lost due to the impacts of the major earthquakes by estimating the number of days it would take for one person to accomplish the lost work. On average, farming organisations lost 40 days of productivity, or 6 days of productivity per full-time staff member as a direct result of the Darfield earthquake. The average total days of productivity lost by farming organisations was heavily skewed by a single farm. That farm was affected by the fault scarp which damaged tracks and paddocks, liquefaction, localized flooding and tree fall. Only non-structural damage to the homestead and sheds were reported. Subsequent major earthquakes proved to be far less disruptive in terms of productivity time losses for farming organisations.

Excluding the single farm which reported over 400 days of lost productivity, farms lost an average of 11 days. Rural non-farming organisations lost on average 469 days of productivity, or 22 days of productivity per full-time staff member. Like the farming sample, the average value of productivity loss is heavily right skewed, and when extreme values are excluded, the average productivity losses for rural non-farming organisations was 11 total days lost. The 22 February event was also highly disruptive for rural non-farming organisations in terms of productivity time losses. With one extreme value removed, the average productivity disruption was 40 days, which is significantly higher than the farming organisation sample. A complete summary of productivity losses for major aftershocks are listed in Table 5.3.

The effects of outliers are pronounced throughout several quantitative impact measures which is not representative for the majority of organisations. While the presence of

TABLE 5.3: Productivity time losses for 4 major earthquakes broken down by farming and rural non-farming samples. Mean productivity losses ($\bar{x}$) are reported in person/-days, which is an estimate of the amount of days needed for one employee to accomplish the lost work. Sample size is reported as N, and % is the percent affected.

Sample	EQ	N	%	$\bar{x}$	10% Trim $\bar{x}$	Std Dev	Skew	Kurt
Farm	4 Sept '10	14	52%	40	12	109	3.66	13.55
	22 Feb '11	11	41%	4	2	8	2.07	3.65
	13 Jun '11	7	26%	0	0	1	3	9
	23 Dec '11	5	19%	2	0	4	2.85	8.28
Non-farm	4 Sept '10	10	71%	469	86	1254	3.04	9.39
	22 Feb '11	7	50%	891	47	2254	2.64	6.98
	13 Jun '11	5	36%	4	2	5	1.53	1.74
	23 Dec '11	4	29%	6	6	13	2	4

extremely affected organisations in the sample are valid and have been consistently reported in previous impact studies [109, 111], it is helpful to report quantitative measures that exclude these outliers. Therefore, the means and trimmed means of quantitative impact measures, such as productivity losses, are reported for illustrative purposes. The trimmed mean values are not intended to be interpreted as more accurate summaries of the sample, but rather are intended to contextualize and contrast the organisations that were moderately affected to those outliers that were more acutely affected.

5.9.3 Reinstatement costs

To assess reinstatement costs, 4 categories were used: (1) asset repair, which are the costs incurred in restoring, repairing, or replacing assets such as buildings or silos; (2) contents repair costs, which are incurred in returning the contents of the asset to their pre-exposure state; (3) clean-up costs, which are incurred for necessary demolition, and/or removing debris, silt, etc.; (4) disruptions costs, which are incurred due to the disruption of activities usually conducted. The total reinstatement costs are the summation of the four categories.

For farming organisations, the largest reinstatement cost was restoring, repairing, or replacing assets. The mean asset repair cost reported by farming organisations was over $87,000, which is significantly higher than any other damage category. Reinstatement costs were not consistent across sampled organisations and the outliers significantly skew average estimations which complicates ranking the remaining damage categories.

Table 5.4: Farm and rural non-farming organisational reinstatement cost summary. Mean costs are reported as $\bar{x}$, and was calculated using only those who were affected. All costs are reported in NZD (NZD $\approx$ 0.8USD).

Sample	Reinstatement	$\bar{x}$	10% Trim $\bar{x}$	Std Dev	Skew	Kurt
Farm	Asset Repair	$87,467	$60,182	$120,927	2.11	5.39
	Contents Repair	$5,601	$4,183	$6,894	1.22	0.11
	Clean-up	$5,880	$2,109	$12,986	3.2	10.94
	Disruption	$8,323	$1,305	$25,595	3.76	14.33
Non-farm	Asset Repair	$177,800	$85,742	$364,690	2.34	5.69
	Contents Repair	$343,478	$13,042	$1,056,095	3	9
	Clean-up	$11,322	$8,842	$15,954	1.1	-0.18
	Disruption	$42,922	$19,471	$102,231	2.16	4.29

To control for the effect of outliers on the mean, trimmed means which exclude the top and bottom 10% of the sample were calculated for each reinstatement cost. All trimmed mean reinstatement costs were lower than their full sample mean and the most proportionally significant decrease was for disruption costs. Overall, the greatest reinstatement cost for farming organisations remained asset repair by a wide margin.

Determining the greatest reinstatement costs is difficult when the mean costs and the trimmed mean costs are compared. For the mean costs, contents repair is the greatest cost of the event by nearly a factor of two. However for the trimmed mean costs, asset repair is the most costly reinstatement of the event and contents repair costs are third to asset repair and disruption costs. A complete summary of these costs can be found in Table 5.4.

Rural non-farming organisations show overall higher total reinstatement costs compared to farming organisations, with significant contributions from asset repair, contents repair and disruption costs. When the trimmed mean of total costs are compared, the reinstatement cost differences between farming and rural non-farming organisations are less exaggerated, and the trimmed mean reinstatement costs are likely a better reflection of a small to medium-sized rural non-farming organisation. Cumulative distribution functions of total costs for responding farming and rural non-farming organisation samples are presented in Figure 5.2.

To control for the bias created by the very large organisations in terms of built infrastructure and total value of holdings the measure of dividing the reinstatement costs by the total or overall value of the organisation's holdings was used. These costs, relative to

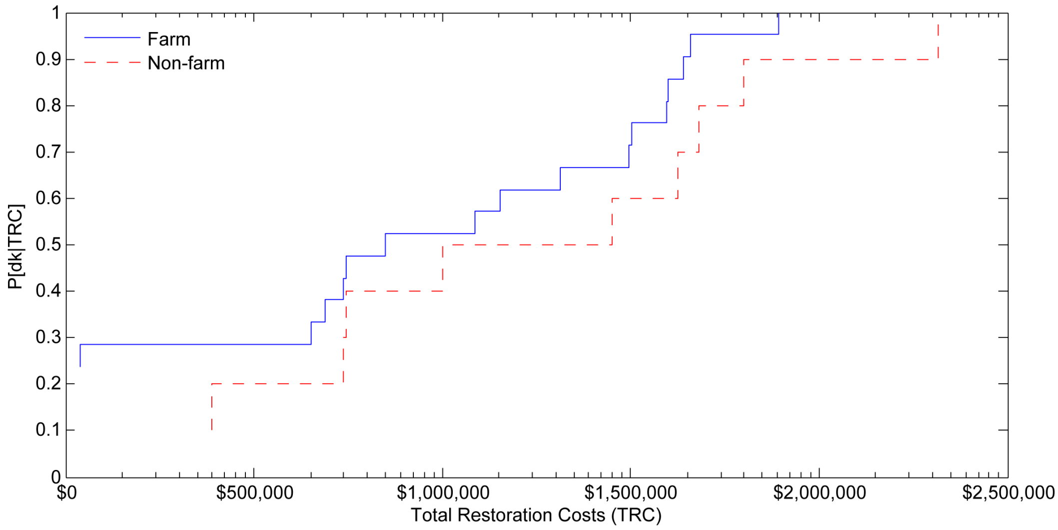

FIGURE 5.2: Cumulative density functions of the total costs for farming and rural non-farming organisations.

TABLE 5.5: Farm and rural non-farming organisation reinstatement costs divided by the organisations total asset holdings value.

Sample	Reinstatement	$\bar{x}$	10% Trim $\bar{x}$	Std.Dev.	Skew.	Kurtosis
Farm	Asset Repair	2.3%	0.7%	5.6%	3.38	11.58
(N=19)	Contents Repair	0.2%	0.1%	0.5%	3.08	9.9
	Clean-up	0.2%	0.0%	0.7%	3.42	11.79
	Disruption	0.2%	0.0%	0.5%	3.15	10.15
Non-farm	Asset Repair	4.1%	0.3%	9.4%	2.44	5.95
(N=7)	Contents Repair	17.1%	0.6%	40.6%	2.45	5.99
	Clean-up	0.8%	0.2%	1.6%	2.25	5.13
	Disruption	1.4%	1.0%	2.0%	1.2	0.17

total organisational holdings, may be biased towards small organisations as proportional losses will be larger for smaller total holdings. It also increases the effect of outliers as only 63% ($N = 26$) of participants chose to report the organisation's total holdings, thus reducing the sample size. This bias is evidenced in the high skewness and kurtosis values illustrated in Table 5.5.

Comparing these data show that for farming organisations, the most significant reinstatement cost relative to the organisation's holdings is asset repair. For rural non-farming organisations, the results are much more variable due to the breadth of industry sectors included in the sample combined with the limited sample size. What is evident in both circumstances is that the presence of extreme values were related to irreparable structural damage or catastrophic structural failure.

Table 5.6: Summary table of damage state to farming and rural non-farming organisational buildings.

Sample	Asset Damage State	N	%
Farm	No Damage	7	26%
	Non-Structural Damage	3	11%
	Repairable Structural Damage	11	41%
	Irreparable Structural Damage	6	22%
Non-farm	No Damage	5	36%
	Non-Structural Damage	2	14%
	Repairable Structural Damage	6	43%
	Irreparable Structural Damage	1	7%
Total	No Damage	12	29%
	Non-Structural Damage	5	12%
	Repairable Structural Damage	17	41%
	Irreparable Structural Damage	7	17%

5.9.4 Damage to structures

Responding organisations were asked to self-assess the damage state of buildings using categorical assessments ranging from no damage to irreparable structural damage. These assessments were not pre-defined in the questionnaire and therefore the results may contain some variability due to respondents assuming differing definitions.

Buildings within the farming sample exhibited statistically higher structural damage states than rural non-farming organisations (M-W U Test: $Z\,adj = 2.1$, $p = 0.03$). More farming organisations experienced structural integrity failures or irreparable damage to structures. The most common type of building damage for both farming and rural non-farming organisations was repairable structural damage. A complete breakdown of the damage states of farming and rural non-farming organisation buildings can be found in Table 5.6.

The higher damage states of buildings were associated with higher asset repair costs. As shown in Figure 5.3, the median asset repair costs for farming and rural non-farming organisations were higher when the building damage state was more severe. For both farming and rural non-farming organisations, the highest asset repair costs were due to irreparable structural damage. However, repairable structural damages was responsible for the majority of reinstatement costs, and in the case of one farming organisation these costs reached as high as 26% of the organisation's total holdings. Therefore, while irreparable damages were generally most costly, repairable structural damages had the potential to reach similar levels. From open descriptions summarizing the damage to the farm, the most commonly cited structural damages were to the homestead (70%), farm sheds (48%), and irrigation infrastructure (44%).

The state of damage to structures was weakly positively correlated to asset repair costs incurred (Spearman Rank Order Correlation $r = 0.60$, $p < 0.05$). Additionally, the costs of repairing those assets strongly correlated to the disruption costs (Spearman Rank Order Correlation $r = 0.92$, $p < 0.05$). To a lesser extent, the costs for clean-up efforts also positively correlated to disruption costs (Spearman Rank Order Correlation $r = 0.68$, $p < 0.05$).

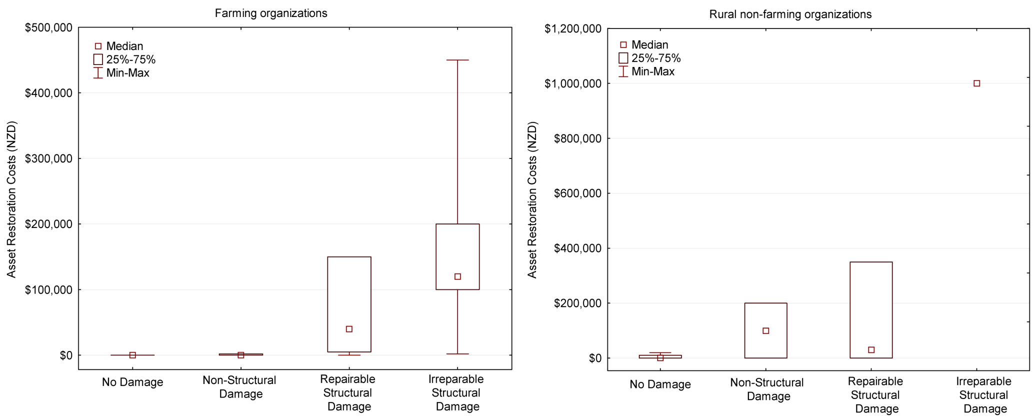

FIGURE 5.3: Asset repair costs categorized by building damage states incurred by farming and rural non-farming organisations.

For rural non-farming organisations, repairable structural damages was the most costly impact, with the median cost equalling 26% of the organisation's total holdings, and one case equalling 100%. Non-structural damage was the only other type of damage that proved costly to rural non-farming organisations, with a medium cost of 4% of the organisation's total holdings. In the open descriptions of damage caused by the event, structural damage and stock damage was referenced by 43% of the rural non-farming sample. The most commonly cited disruption, referenced by 50% of the sample, was the lost time needed to clean up non-structural damages.

For rural non-farming organisations, the severity of damage to structures was strongly positively correlated to disruption costs (Spearman Rank Order Correlation $r = 0.94$, $p < 0.05$), indicating that the primary source of disruption costs were related to shaking damage. The costs of asset repair were correlated to the costs of contents repair (Spearman

Rank Order Correlation $r = 0.90$, $p < 0.05$). The data illustrate that the majority of disruptions experienced by the rural non-farming organisations were non-structural and contents related.

5.9.5 Organisational performance

Farming organisational performance following the Darfield earthquake showed no correlation to asset reinstatement costs, indicating that while organisations may be heavily affected in terms of asset damage and disruption costs, these do not necessarily translate into performance decreases. In fact, most farms (66%) observed increases in revenue in 2010 and 2011, with an average increase of 7.4%. Three farms reported no change in revenue and only one farm reported a revenue decrease of 0.5%. In terms of decreased revenue, only one farm stated revenue levels were below average following the Darfield earthquake. The drop was attributed to market changes and not a result of the earthquake sequence. Revenue increases were directly attributed to market changes, and 38% of all explanations for revenue changes were either predominately or directly attributed to commodity prices. Two farms observed decreases in profits, one with a decrease of 0.5% while the other omitted reporting a percentage but observed no overall change in revenue. One farm stated that the decreased profits were a result of the time required to repair damages from the earthquake. In total, only two cases cited the Darfield earthquake as having a direct negative impact on revenue or production levels, suggesting that measures of productivity and production are different as labour production losses did not inhibit production in this case. A yearly breakdown of revenue changes can be found in Table 5.7.

Surprisingly, asset losses for farms appeared to have a positive effect on revenue. Farms with higher total asset losses observed increases in revenue during the 2010 (Spearman Rank Order Correlation $r = 0.79$, $p < 0.10$) and 2011 fiscal years (Spearman Rank Order Correlation $r = 0.88$, $p < 0.05$). These changes in revenue for farms were viewed as increases in organisational performance for 2010 (Spearman Rank Order Correlation $r = 0.64$, $p < 0.10$) and 2011 (Spearman Rank Order Correlation $r = 0.70$, $p < .05$). It is unlikely that organisational repair costs drove performance increases. The primary reason cited by farms for the increases in revenue was the very strong international commodity markets during the months following the Darfield earthquake. Despite incurring

Table 5.7: Average annual revenue change for farming and rural non-farming organisations between 2007-2011. The percent changes reported are compared to the previous year. For example, a decrease of -3% in 2008 states that revenue for the 2008 fiscal year was 3% lower than 2007.

Sample	Year	$\bar{x}$	Std.Dev.	Skew.	Kurt.
Farm	2007	1%	6%	3.20	11.31
(N=13)	2008	-3%	14%	-3.27	11.46
	2009	6%	9%	1.10	-0.62
	2010	8%	10%	1.38	0.91
	2011	5%	7%	1.24	0.8
Non-farm	2007	21%	44%	2.22	4.95
(N=6)	2008	22%	43%	2.21	4.9
	2009	28%	41%	2.03	4.26
	2010	27%	42%	1.96	3.87
	2011	35%	39%	0.91	0.06

asset losses, the production levels for affected farms were not affected, and therefore the farms revenue increases were a response to the increased value of goods on the international markets.

While overall, rural non-farming organisational performance appeared to be relatively unaffected by the earthquake, revenue changes for rural non-farming organisations were strongly negatively correlated to disruption costs when divided by total holdings (Spearman Rank Order Correlation $r = -0.97$, $p < .05$). No other significant correlations were observed for rural non-farming organisations, although it should be noted that asset losses and clean-up costs showed negative relationships to revenue changes, and warrant further analysis in future studies. When asked to explain the changes in revenue, rural non-farming organisations cited the reasons were due increased customer numbers in the region. These customers were reported to be from the city of Christchurch to either view the damage caused by the Darfield earthquake or to escape the damage caused by the Christchurch earthquake. Additional customer traffic was due to construction crews working in the area to repair damages. In one instance, a respondent noted there to be an increase in the rural population, with residents of Christchurch opting to relocate to the rural areas surrounding the city.

5.9.6 Hazard intensity metrics

To understand how organisational costs were related to the Darfield earthquake, different hazard intensity metrics were compared against measures of organisational impact. The hazard intensity metrics used were Modified Mercalli Intensity Scale (MMI), GNS modelled MMI isoseismals, peak ground acceleration (PGA), and distance from the fault. MMI data was generated from felt reports collected by the GeoNet website, and interpolated using the ordinary kriging method and the exponential semivariogram model in ArcGIS. PGA data from the Darfield earthquake were retrieved from the GeoNet website [203], and interpolated the same method as used with the MMI dataset. Interpolated MMI and PGA values were then assigned for each organisation as an assessment of the felt shaking intensity experienced. The GNS modelled MMI isoseismal projections, shown in the inset of Figure 5.1, were assigned to organisations by isoseismal band.

The hazard intensity metrics were analysed for associative patterns with impacts (such as reinstatement costs, productivity time lost, and revenue change) organisational attributes (such as number of employees, total area used by the organisation), and the number of buildings. Felt MMI values derived from felt reports correlated with several different measures of farming organisational damage and disruption costs. GNS modelled MMI isoseismal values (shown in the inset of Figure 5.1) showed no correlations to farming or rural non-farming organisational damage or repair costs. This is due to the vast majority of the sample (80%) located within the MM8+ isoseismal band, with the remainder in the MM5-7. The categorical isoseismals were too coarse and not suitable for the purposes of this study. Interpolated peak ground accelerations (PGA) from the event also did not correlate with farming or rural non-farming damages. Lastly, for both farming and rural non-farming organisations, the distance from fault was not found to correlate to repair costs or structural damages. However in one instance where the fault scarp crossed a farming organisation's land, there was significant damages associated repair costs as well as productivity time losses that were directly attributable to the disruptive impacts of the ground surface damage. These impacts were not observed in farms or rural non-farming organisations that were near but not directly affected by the fault scarp.

5.9.6.1 Felt MMI and organisational impacts

For farming organisations, the three strongest corollaries to the interpolated felt MMI values were the productive time lost per staff ($r = 0.68$, $p < 0.05$), asset repair costs divided by total holdings ($r = 0.67$, $p < 0.05$), and asset repair costs divided by total holdings ($r = 0.63$, $p < 0.05$). As shown in Table 5.8, felt MMI values were also found to be positively correlated to several other reinstatement cost metrics and suggests that the perceived shaking intensities as recorded by felt reports from GeoNet website was an accurate predictor of farm reinstatement costs as well as the productivity time lost.

In contrast to the results found for farming organisations, felt MMI values for rural non-farming organisations showed no correlation to organisational damages or total disruption costs. Of the correlations found, one of interest is the very strong negative correlation of total days closed and total asset damages divided by total holdings. This relationship is counter-intuitive as one might expect a positive relationship between closure and damages, where the greater damage an organisation experiences should increase the likelihood of forced closure. It is unclear whether such a strong relationship is meaningful or specious and a product of the limited sample size. One potential explanation for this strong correlation could be the ability of small organisations to relocate. Although there is little evidence for this relationship, in one instance, an organisation that experienced high asset repair costs relative to the organisation's total holdings were able to relocate to a temporary structure in the vacant lot directly adjacent to their heavily damaged original premises. A complete summary of rural non-farming correlations for felt MMI values can be found in Table 5.9.

5.9.7 Farming organisational impact modelling

The purpose of this section is to identify what hazard intensity metric can be used to estimate the damage to farming organisations following an event. Rural non-farming organisations will be omitted from this section due to the wide sectoral range of the very limited sample set, making this form of analysis untenable. As shown in Figure 5.4, higher damage states to organisational assets for farming organisations are predominately located in areas of higher felt MMI values. While damaged assets are found in areas of felt MMI 5 and below, there appears to be a marked increase in the likelihood of

TABLE 5.8: Farming organisational damage and attribute correlation matrix (Spearman Rank Correlation)

	Asset Repair Costs	Contents Repair Costs	Clean-up Costs	Disruption Costs	Total Costs	Asset Repair Costs/Holdings	Contents Repair Costs/Holdings	Clean-up Costs/Holdings	Disruption Costs/Holdings	Total Damage/Holdings	Full-time Staff	Part-time Staff	Organisational Area	Number of Buildings	Productive Time Lost per Staff
Felt MMI	.62*	.37	.58*	.52*	.53*	.67*	.29	.51	.63*	.56*	.24	.13	.32	.09	.68*
Asset Repair Costs	1	.59*	.72*	.72*	.95*	.97*	.51*	.62*	.69*	.91*	.62 *	.43	.65*	.27	.89*
Contents Repair Costs		1	.48*	.35	.72*	.58*	.96*	.31	.29	.72*	.28	.04	.19	-.01	.73*
Clean-up Costs			1	.65*	.69*	.70*	.29	.98*	.64*	.66*	.32	.27	.44	.18	.72*
Disruption Costs				1	.71*	.73*	.29	.59*	.99*	.71*	.37	.39	.57*	.45	.63*
Total Costs					1	.91*	.61*	.59*	.67*	.97*	.53 *	.3	.59*	.14	.82*
Asset Repair Costs/Holdings						1	.56*	.67*	.72*	.94*	.44	.31	.54*	.17	.88*
Contents Repair Costs/Holdings							1	.32	.25	.66*	.08	-.1	.04	-.23	.71*
Clean-up Costs/Holdings								1	.62*	.62*	.11	.12	.25	.14	.51
Disruption Costs/Holdings									1	.70*	.24	.33	.5	.5	.94*
Total Costs/Holdings										1	.39	.18	.51*	.05	.86*
Full-time Staff											1	.61 *	.63 *	.67 *	.43
Part-time Staff												1	.65*	.4	.37
Organisational Area													1	.59*	.18
Number of Buildings														1	.11
Productive Time Lost/Staff															1

* Denotes p<0.05

TABLE 5.9: Rural non-farming organisational damage and attribute correlation matrix (Spearman Rank Correlation)

	Asset Repair Costs	Contents Repair Costs	Clean-up Costs	Disruption Costs	Total Costs	Asset Repair Costs/Holdings	Contents Repair Costs/Holdings	Clean-up Costs/Holdings	Disruption Costs/Holdings	Total Damage/Holdings	Days Closed	Full-time Staff	Part-time Staff	Organisational Area	Number of Buildings	Productive Time Lost per Staff
Felt MMI	-.63*	-.53	-.51	-.3	-.63*	-.44	-.45	-.15	.02	-.21	.12	-.76 *	-.56	.35	-.32	-.32
Asset Repair Costs	1	.83*	.53	.6	.88*	.96*	.34	-.08	.2	.11	.11	.88 *	.71	.19	.72*	.24
Contents Repair Costs		1	.38	.39	.90*	.71	.71	-.43	-.05	.49	-.33	.77 *	.77*	-.07	.46	.31
Clean-up Costs			1	.35	.48	.31	-.24	.81*	.49	-.19	-.06	.69 *	.25	.15	.36	.2
Disruption Costs				1	.66*	.59	.21	.39	.96*	.45	.17	.37	.01	.11	.37	.63
Total Costs					1	.78*	.54	-.11	.33	.5	.05	.80 *	.81*	-.19	.55	.4
Asset Repair Costs/Holdings						1	.41	0	.39	.22	-.11	.82 *	.47	.21	.73	.38
Contents Repair Costs/Holdings							1	-.39	.03	.85*	-.79	.38	.26	-.49	.11	.83*
Clean-up Costs/Holdings								1	.59	-.11	.65	.06	0	-.03	.27	.33
Disruption Costs/Holdings									1	.37	.08	.11	.03	.03	.08	.68
Total Costs/Holdings										1	-.95*	.09	.32	-.71	-.19	.83*
Days Closed											1	-.16	-.36	.04	.31	.05
Full-time Staff												1	.62 *	.09	.67 *	.09
Part-time Staff													1	-.33	.21	.07
Organisational Area														1	.56	-.3
Number of Buildings															1	.09
Productive Time Lost/Staff																1

* Denotes p<0.05

asset damage for sample population in areas of approximately felt MMI 5.5 and above. Additionally, 80% of organisations that suffered irreparable structural damages were located in areas of felt MMI 6.0 and above.

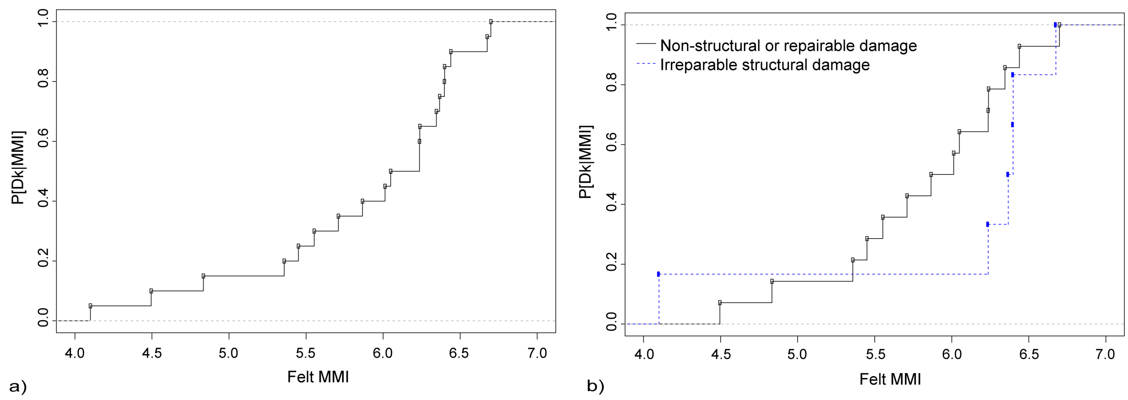

FIGURE 5.4: Empirical cumulative density functions for farming organisational structural damage: a) Structural damage to farming organisation infrastructure with all damage states; b) Structural damage to farming infrastructure broken down by repairable and irreparable damage states.

As stated previously, farming organisations that experienced structural damage to assets incurred higher repair costs. Although asset damage states of farms in higher felt MMI areas were not significant, asset repair costs for farms were found to be significantly higher. Other hazard intensity metrics did not correlate and have been omitted. Therefore, in modelling the likely costs of asset repair, which was the most costly aspect of the event by a wide margin, felt MMI is the most appropriate hazard intensity metric to use. Felt MMI data are also a more appropriate hazard intensity metric to use in estimating asset repair costs divided by total organisational holdings.

A linear regression model of asset repair costs and felt MMI is illustrated in Figure 5.5. A linear non-parametric model was chosen for parsimony and to decrease the likelihood for type 2 error given the relatively limited dataset. The weak association between asset repair costs and felt MMI shows that while felt intensity of ground shaking is a reasonable hazard intensity metric to use in modelling the asset repair costs to farming organisations, there are other factors that are important to the incurred costs following an event. Earlier, it was shown that both the number of full time employees as well as the organisational area were positively correlated to asset repair cost. Although several other theoretical organisational factors may also correlate to the asset repair costs, given the limited sample size, only the statistically significant factors were included for analysis.

Other possible factors that could control asset costs are farm sector or the number or types of buildings on farm. However further work is required to test these possible factors, and for the purposes of this study, only the number of full time employees and the organisation areas were used.

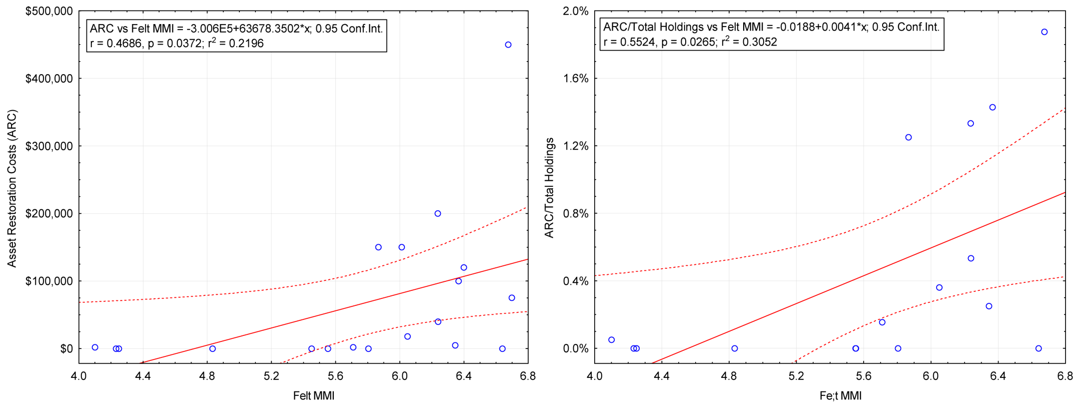

FIGURE 5.5: Asset repair costs (ARC) with 95% confidence bands *vs* Felt MMI (left) and ARC/total holdings *vs* Felt MMI with 95% confidence bands (right).

To create weightings using the number of full time staff and the area of the organisation, both values for each organisation were given a percentile ranking from empirical cumulative density functions. The weighting scheme used is shown in Equation 5.1 below:

$$Relative\, Impact\, Factor = \left[\frac{P[Dk|Staff_i] + P[Dk|Area_i]}{2}\right] \times FeltMMI_i \tag{5.1}$$

where $P[Dk|Staff]$ and $P[Dk|Area]$ is the percentile ranking of a given organisation's number of full-time staff and area respectively compared against the sample group; $_i$ denotes the given organisation. The resulting metric (Relative Impact Factor or RIF) when plotted against the total asset repair costs which, as shown in Figure 5.6, illustrates a stronger regression. Accounting for these two organisational attributes provides a better linear fit to the relationship between asset repair cost data and the Relative Impact Factor. Additionally, an improved regression was found for asset repair costs divided by the organisation's total holdings and the relative Impact Factor.

From these results, estimating the expected repair costs of farming organisations within a given area following an event should be a function of the interpolated MMI values generated from felt-reports, the farming organisation's overall land use and the number

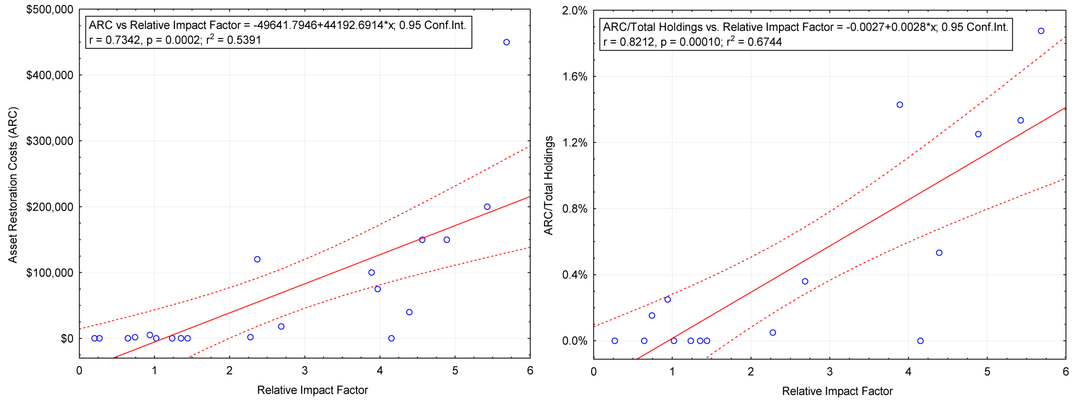

FIGURE 5.6: Asset repair costs (ARC) *vs* Relative Impact Factor with 95% confidence bands (left) and ARC/total holdings *vs* Weighted MMI with 95% confidence bands (right).

of employees. Equation 5.2 estimates the total asset repair costs (TARC) of a given sample population is shown below:

$$TARC = \sum_{i=1}^{N} n_p \Big(RIF \Big) - 0.01 n_p \tag{5.2}$$

with n_p representing the median total asset value of the sample. All negative values generated by the equation should be conditionally recoded to zero. The limitation to this function is that it must be used with interpolated felt MMI data and will significantly overestimate the asset repair costs if used with modelled isoseismals.

5.9.8 An example with two idealized scenarios

Applying this weighting scheme to 10 hypothetical organisations and comparing the cost estimates between two idealized scenarios illustrates the cost estimation differences generated by the TARC equation. In the first scenario, Scenario A, the organisations with fewer full-time staff and smaller organisational areas are located in areas of lower intensity shaking while the organisations with a greater number of full-time staff and larger organisational areas are located in areas of higher shaking intensities. In the second scenario, Scenario B, the shaking intensity distribution is held constant, but the locations of the organisations are changed so that the organisations with more full-time staff and organisational area are in the low intensity shaking areas. Scenario A represents a circumstance where the larger organisations happen to be located in the areas of higher intensity shaking and therefore should produce higher total asset repair costs than in Scenario B. As shown in Table 5.10, in estimating the sum total asset repair costs of 10 organisations with an assumed median value of $5,000,000, the TARC equation estimates the difference in total costs incurred between the two scenarios was $268,000 despite the two scenarios using the same felt MMI distribution.

TABLE 5.10: Illustrative example of 10 hypothetical organisations located in two scenarios, with the projected costs of both scenarios as well as the cost differences using the TARC model.

			Scenario A (SA)		Scenario B (SB)		SA-SB
Org_i	$P[Dk\|Area_i]$	$P[Dk\|Staff_i]$	MMI	Cost	MMI	Cost	$\Delta Cost$
1	0.1	0.1	4	$ 0	6.7	$ 0	$ 0
2	0.2	0.2	4.3	$ 0	6.4	$ 14,000	$ (14,000)
3	0.3	0.3	4.6	$ 19,000	6.1	$ 41,500	$ (22,500)
4	0.4	0.4	4.9	$ 48,000	5.8	$ 66,000	$ (18,000)
5	0.5	0.5	5.2	$ 80,000	5.5	$ 87,500	$ (7,500)
6	0.6	0.6	5.5	$ 115,000	5.2	$ 106,000	$ 9,000
7	0.7	0.7	5.8	$ 153,000	4.9	$ 121,500	$ 31,500
8	0.8	0.8	6.1	$ 194,000	4.6	$ 134,000	$ 60,000
9	0.9	0.9	6.4	$ 238,000	4.3	$ 143,500	$ 94,500
10	1	1	6.7	$ 285,000	4	$ 150,000	$ 135,000
Total	-	-	-	$ 1,132,000	-	$ 864,000	$ 268,000

Note: n_p value applied was $5,000,000

5.10 Summary and conclusions

The effects of the Canterbury earthquake sequence on farming and rural non-farming organisational stock and flow damages illustrate fundamentally different organisational responses. Farming organisations were less likely to report being affected, lose fewer days of productivity recovering from the event, and incur lower reinstatement costs for asset and contents damages, as well as lower reinstatement costs for clean-up activities and disruption. However, farm buildings, specifically the homestead, had more damage than rural non-farming organisation buildings. The inclusion of the homestead as an organisational asset was unique to the farming sample group and structural damages to the homestead represented a major contributor to asset repair cost estimates. These structural damages for farms represented the largest damage in terms of reinstatement costs, and were strongly correlated to disruption costs indicating that the majority of disruption was related to restoring on-farm infrastructure. For dairy farms that had drops in milk production, these losses were absorbed by the national co-op level.

While farming stock losses did not cause significant organisational flow disruptions, the results suggest that their is relatively low reliance on stock as an essential means of production, which in part was due to the fortunate timing of the event. If the Darfield earthquake were to have occurred later in the growing season where disruptions to irrigation infrastructure would have critically affected dry growth production or stock health, it is likely that there would have been larger flow effects on the farm level. In the case of dairy farms, where stock losses had a critical impact on production, the ability to relocate herds to neighbouring operating milking sheds was the most important factor. Additionally, the major dairy co-op did not penalize drops in production for affected farms, which effectively transferred the individual farmer's loss to the national co-op. These drops in production were the result of less frequent milking (a result of managing additional herds with fewer operating dairy sheds) or spoilt milk due to drops in electricity.

Rural non-farming organisations experienced significantly more damage to non-structural assets and consequently incurred much greater contents repair, clean-up and disruption reinstatement costs. These damages were usually the result of unrestrained stock items that fell during ground shaking. In most cases, non-structural damage was the primary reason for closure. Seventy-five percent of the rural non-farming sample were forced to close for an average of 4 days. In certain cases, supply issues prevented restocking which led to a decrease in organisational performance. However overall, the rural non-farming sample group saw no change in organisational performance in 2010 and 2011.

Rural non-farming organisations suffered greater productivity losses and repair costs than farming organisations. Similar to what was found for farming organisations, rural non-farming organisations with more full-time staff incurred higher asset repair costs as well as total reinstatement costs, as well as asset repair costs divided by total holdings. One important distinction between farming and rural non-farming organisations was that rural non-farming organisations were forced to close, which halted production and/or lost sales during that time which directly translated into revenue decreases. Furthermore, rural non-farming organisations were more likely to be affected by subsequent aftershocks than farming organisations, which in most cases required closing the organisation for a period of time to assess damages before allowing customers on the premises. Despite the closures and losses, rural non-farming organisations saw, on average, increases in revenue during the Canterbury earthquake sequence. These increases were attributed to increased customer numbers from the city of Christchurch, either to view damage to the area or escape the damage to the city or construction teams in the area to repair damage.

With regards to identifying potential predictors of earthquake-related impacts for farming organisations, the number of staff employed and the total area used by the organisation were found to be significantly correlated to reinstatement costs. Unsurprisingly, these results appear to suggest that the larger organisations had more assets that were likely to be damaged by the earthquake. The association between repair costs and organisational size is likely because farms with more staff, in general, had more buildings and greater farmland which ultimately led to greater asset and disruption vulnerability. However, there was no observable association between revenue or profit decreases and organisational size; despite significant asset losses incurred on-farm, both small and large farming organisations were able to maintain production or return to pre-earthquake levels of production quickly. This is likely due to the fact that the vast majority of farms reported that the Canterbury earthquake sequence had no large effect to the base of production, in combination with the relatively strong commodity prices during the year. These results suggest that the Canterbury earthquake sequence overall had a relatively small effect on organisational performance when compared to the effect of a strong commodities market can have for the farms.

For farming organisations, felt MMI values were significantly correlated to a number of different impact metrics including: asset repair costs, clean-up costs, disruption costs, the sum of all costs (total costs), asset repair costs divided by total holdings, disruption costs divided by total holdings, and productivity time losses per staff member. These results suggest that for farming organisations, felt MMI is an accurate predictor of the loss in productive time of labour, likely damage costs as well as the damage costs relative to the overall value of the organisation. Linear regressions illustrating the association between asset repair costs and felt MMI values have been presented. Importantly however, the amount of reinstatement costs incurred by either farming or rural non-farming organisations showed no effect on organisational performance, or changes in revenue or profitability.

The results of this study show there to be a wide range of direct and indirect impacts to rural organisations, which demonstrate the need for further data collection from organisations following earthquakes. Future earthquake impact studies that focus on organisations should include rural industry sectors as farming organisational impacts were distinctive to that of rural non-farming organisations, and further data collection will help constrain variability for loss modelling simulations such as HAZUS and Riskscape.

5.11 Acknowledgements

The authors gratefully acknowledge funding support from the New Zealand Natural Hazard Research Platform (NHRP), Ministry for Agriculture and Forestry (MAF), Earthquake Commission (EQC), Ministry for Civil Defence and Emergency Management (MCDEM), and the University of Canterbury Mason Trust. We acknowledge the New Zealand GeoNet project and its sponsors the Earthquake Commission (EQC), GNS Science and Land Information New Zealand (LINZ), for providing data/images used in this study. Finally, we gratefully acknowledge the time and effort taken by respondents who chose to participate in this study. This research is part of the Resilient Organisations research program which has initiated a longitudinal study of organisations affected by the Canterbury earthquakes. Results from the program will be made available via the organisation's website: www.resorgs.org.nz.

Chapter 6

The 2010 Southland snowstorm

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6.1 Overview

This chapter presents the findings from organisations affected by a major snowstorm event in the Southland district that occurred at approximately the same time as the Darfield earthquake, and was included in the thesis as a means to compare the effects of two different natural hazards on rural organisations in New Zealand. The data analysed in this chapter were collected using the same questionnaire presented in Chapter 3, and in the context of the thesis, the results from the 2010 Southland snowstorm survey are most directly comparable to the results presented in Chapter 3. Included in this chapter are the impacts of the snowstorm, and the factors helpful in mitigating these impacts. Additionally, semi-structured interviews conducted with support agencies, trade organisations, rural non-farming organisations and affected farmers were conducted to better contextualize the results of the questionnaire and to gather primary source material. The results illustrate the validity of using a single questionnaire in two different post-disaster contexts, and more broadly, identify thematic characteristics of rural organisational and community resilience, such as the adaptive strategies and psychosocial challenges that result from working in a post-disaster setting.

The theoretical framing in this chapter draws from both the engineering resilience and the ecological resilience traditions, with the use of the SUST vulnerability model. The chapter views organisations as both individual systems as well as a constituent part of a larger system. In each case, system stability states are viewed in context of each paradigm, with the engineering approach ascribing to a single stability state, and the ecological approach considering several. In both circumstances, the SUST vulnerability approach is used, as resilience comprises both organisational as well as rural community vulnerabilities. The mention of resilience is therefore attributable to both the engineering and ecological resilience definitions as explained in Chapter 1. In determining factors affecting systemic (the community of rural organisations) resilience, the SUST vulnerability model was employed, and techniques similar to Chang and Falit-Baiamonte [294], Alesch [4], and Smith [14] are used.

6.2 Contributions

Mr. Whitman, with the assistance and supervision of Dr. Wilson, developed the research design and methodology. Dr. Wilson also assisted in the data collection process and select contextual interviews. Dr. Vargo and Dr. Seville assisted Mr. Whitman in the development of the questionnaire design and Dr. Vargo, Dr. Cole, Dr. Seville, and Dr. Wilson all contributed to the revision process of the manuscript.

6.3 Abstract

On 18 September 2010, rural organisations in Southland, New Zealand experienced an unseasonably late snowstorm and period of cold weather, causing structural damage to buildings in Invercargill and widespread livestock losses and livestock production decreases across the region. Farming organisations were most severely affected, with

livestock losses, livestock management challenges, and consequent revenue decreases creating extreme workloads and elevated stress for affected farmers. These impacts to farming organisations created subsequent flow-on effects for the secondary and non-farming industries. The single most significant mitigating factor was the independent and rise in commodity prices later in the year, which offset financial losses and prevented some farms from exiting the industry.

6.4 Introduction

Storms are one of the most frequent and destructive hazards worldwide, costing approximately \$44 billion and affecting 33 million people on average each year worldwide [34]. The land-based primary industries are especially vulnerable to storm events as extreme weather is a major contributor to production losses [307], and with decreased recurrence intervals of high-intensity storms forecasted for many areas [308] – including New Zealand [309] – Nelson et al. [310] has found that the investments required to offset the predicted losses to agriculture worldwide exceed \$7 billion (USD) annually.

In New Zealand, severe snowstorms have historically posed a frequent hazard in some locations to farming organisations, their families, and rural communities [128, 130, 311]. New Zealand is a small temperate island nation and snowstorms which deposit more than a few centimeters at low elevations (i.e. <400m above sea level) are rare [89] nor are they expected by farming communities. Additionally, they typically only occur in the winter period between late May and August [89, 312]. Snowstorms can disrupt electrical and telecommunication services, disrupt transportation networks, collapse structures, damange crops, and threaten livestock welfare, all of which can threaten the viability of farming organisations [18]. These events can also have several psychosocial impacts for the farmer as well as their family, often brought on by extreme workloads and isolation [128, 128, 130, 130, 311].

In September 2010, a snowstorm and period of unseasonably cold and wet conditions occurred in the District of Southland, which is the southern most district in New Zealand. The event was widely reported in the national press because the snowfall depths were sufficient to collapse roofs in the city of Invercargill, and the event occurred in the middle of lambing for many of the sheep farms in the region [313]. As the cold weather continued, the lambing losses increased which threatened the viability of affected farms and posed up and downstream impacts for farm-support organisations as well as to the local business community. The Ministry of Agriculture and Forestry assessed the event to be 'medium-scale' on its three level adverse events scale rubric, which activated financial and personnel support for the region. As a result, relief efforts were initiated by Southland Civil Defence, the Rural Support Trust Southland, and farm-support industry groups [314] to assist affected farming organisations.

Given the vulnerability of farming organisations to the effects of major snowstorms in New Zealand and the interdependencies of rural businesses, the 2010 Southland snowstorm provides an opportunity to assess the impacts of the event, comparing the challenges experienced and the coping mechanisms employed by farming and non-farming organisations, to explore the interdependencies between the farming and non-farming sectors, and to assess the effectiveness of support agencies' efforts. To address these objectives, regional organisations were contacted following the event with a questionnaire designed to characterize the impacts of the 2010 Southland snowstorm on farming and rural non-farming organisations, identify what was found to be disruptive for affected organisations and what factors helped in mitigating those disruptive impacts. Semi-structured interviews were also conducted with affected organisations, industry representatives, and emergency support organisations to better contextualize the event and its impacts.

6.5 Snowstorms and their disruptions

The disruptiveness of a snowstorm is very context-specific. In New Zealand, snow accumulations of 15 cm or greater can be massively disruptive, as in events such as the 2006 'Canterbury Snow Storm' [312] which brought the city of Christchurch and surrounding rural areas to a stand still for several weeks. In other areas, such as the Northeastern United States, accumulations of 107 cm which occurred in the 'Blizzard of 1993' only disrupted businesses and schools for a few days [315]. This large discrepancy in resulting impacts to vastly different levels of accumulation illustrate that although certain regions may not experience the same hazard intensity, the risk perception of the hazard plays an important role in the resulting preparedness and ability to respond – and ultimately to recover.

From case studies conducted in the Northeastern United States, the factors that are have been found to affect snow events are: (1) meteorological variations, (2) governmental responses and support, (3) actions of the public, (4) meteorologists and the media, and (5) climate and experience with past events [315]. The meteorological factors that are important to consider are the total snow accumulation, snowfall rate, snow density and air temperature, wind and duration [315]. Related to meteorological variations is the timing of the event, which is of consequence because of human factors; for example storms that occur mid-day cause severe traffic congestion as schools and workplaces dismiss simultaneously, but storms that occur overnight or on the weekend can compel many to shelter in place [315].

The ability to forecast high snowfall levels and communicate these forecasts effectively can help the public prepare for events, and thus help decrease the overall impact of the event. The media response to forecasted snowstorms can lead to a 'mad rush', which occurs when the public stock up on essential supplies (e.g. bread, milk) in advance.

Areas with frequent snowfalls may also prepare with developing specialist capabilities such as maintaining snow removal equipment, which is the most stark differences between the Northeastern United States and New Zealand. Due to the frequency of snow storm events in the Northeastern United States, significant snow removal capacity are built into county budgets [316]. In New Zealand, snowfall levels are usually not frequent or great enough to warrant such expenditures, and snow is often left to melt away due to the infrequency of sustained freezing temperatures. However, governmental funding is made available for farming organisations when the snowfall event is deemed an adverse event [169].

6.5.1 Storm impacts to organisations in the New Zealand context

The greatest accumulation of snow in New Zealand is generally located in the mountainous regions; however some snow is expected each year in the south and the eastern parts of the South Island [89]. The South Island of New Zealand has relatively regular experience with snowstorm events. Two notable and recent examples are the 1992 'Big Snow' and the 2006 'Canterbury Snowstorm', both of which occurred in the Canterbury District. Both of these events caused structural damage, disrupted critical services such as electricity, telecommunications and water, and difficult road conditions which often prevent employees from reaching their place of work [317].

Generally, snowstorms will disrupt travel networks and critical services (lifelines) which lead to the closure of workplaces, schools and day-care centres [315]. When organisations such as schools or day-care centres are forced to close, some staff have to remain at home to look after children [139]. These impacts can negatively affect organisational cash flow in different ways. For example, customers may be unable to reach businesses, businesses may be unable to remain open, or the loss of electrical services can cause businesses with perishable goods to lose inventory [318]. The loss of critical services or utility lifelines following a natural disaster is often regarded as one of the most costly impacts as it can have significant flow-on impacts for individual organisations, industry sectors, and the regional economic activity [221, 319].

For rural areas, disrupted travel networks can create psychosocial issues. Isolation has been identified as an issue, most notably in areas that have lost power and telecommunications, and also proved inaccessible by road [317]. Stress due to financial concerns, extreme workloads, and the dead stock are also challenges that are faced by farming organisations.

The effects of extreme workloads and stress were found to be a substantial issue in the 1992 Canterbury snowstorm as well as the 2006 Canterbury snowstorm [128, 130, 317, 320]. Several studies identify the inter-relationship between the impacts of natural disasters and psychological distress in rural settings [13, 286, 286]. While stress has been long understood to be a common feature of the farming industry [321–323], natural disasters have been ranked by farmers as one of the most stressful events faced [286]. Further, natural hazards have been shown to have long-lasting psychosocial, mental, and community impacts [13].

Negative impacts to farming organisations also have direct implications for regional non-farming organisations. Non-farming rural organisations often rely on farming organisations for production purposes or as their customer base, and when farming organisations perform poorly or are negatively affected by a natural hazard, the local economy suffers as a result [18, 246]. Pritchard et al. [246] found farms and farm households heavily rely on local towns for recurrent purchases, maintenance purchases, or services. When available, farms have been shown to opt for local procurement of services or capital [246].

In circumstances where a natural disaster only directly impacts farming organisations, Edwards et al. [18] found that the effects of drought for farms in rural Australia translated into decreased farm and farm household spending which negatively impacting the local non-farming organisations.

Livestock losses are generally one of the most significant concerns for farming organisations during snowstorms in New Zealand. Because livestock are not wintered indoors in New Zealand, specially orientated shelter based on historic wind patterns (known as shelterbelts or windbreaks) play a vital role in protecting livestock in a severe weather event like a snowstorm [320, 324–330]. In 1992, a major snow storm occurred in the Canterbury Region of New Zealand and killed over 1 million stock [320]. The snowfall occurred in August near peak lambing and it was reported that most farmers suffered 20-30% lambing losses, with some losing as much as 60% [320]. Due to the snow cover, supplemental feed was required for the surviving stock, as snowfall limit the availability of forage to graze [331].

6.5.2 The effects of the 2006 Canterbury snowstorm

In 2006, a major snowstorm event blanketed most of the Canterbury region of the South Island in snow depths of 10cm or more [130, 131, 311] which resulted in over $35 million in insurable losses [312]. The snow was characterized as heavy, with recorded examples of building collapse, and persisted for 7 weeks in some areas due to an unseasonably cold period following the event [131]. Smith [130] and Wilson et al. [131] found the common impacts included the loss of communications, loss of power, road closures, damage to trees and fences, issues relating to the feeding of stock and the longevity of the snow, and the resulting financial psychological stress. These impacts caused staff shortages, financial hardships for employers as well as for those unable to get to work, school closures, and social isolation [131].

The snowstorm was found to impact farming organisations and the rural communities more severely than the urban sectors or communities, particularly because of the extended period of critical service outages which, notably in the case of telecommunication failure, exacerbated the effects of isolation [130, 131]. For urban areas, the major challenges faced were structural damage caused by snow loading and from snow remaining on structures for so long, business interruption due to employees being unable to get to work or deliver services, critical service disruptions as well as increased traffic accidents. For farming organisations, despite the event occurring after a period of favourable conditions where stock were in good condition and supplementary feed reserves were strong, the prolonged duration of the snow cover exhausted much of the supplementary supply [131].

Livestock losses were not a common impact in the majority of affected farms [311]. Of the stock losses that did occur, the majority were sheep, and less commonly deer. The stock management challenges included removing stock from higher elevations, resulting in a decrease in feed availability and the requirement of supplemental feed. Livestock were often trapped in the snow which created long periods of exhausting work for the farmers [311]. Rescuing stock required the labour intensive process of snow raking which involved digging sheep out of snow drifts, or pulling stock from the snow one at a time using 4-wheel vehicles [311]. Smith [130] notes that the timing of the event was crucial as stock were not calving or lambing; farmers stated that if the snow had fallen during lambing or calving, stock losses would have been disastrous.

Kelly and Smith [311] found that the farms less accustomed to snow were ill-prepared to manage the impacts and consequently performed more poorly. Despite the majority of farms sampled by Kelly and Smith [311] having an electrical generator on-site, the generators were only capable of providing power for domestic purposes, maintaining a water pump, or a freezer. Ultimately however, the lack of power was cited as an annoyance, and was not as serious as the effect of forced isolation the event caused [311]. The impact of the storm was also cited as being challenging financially, which compounded farmer stress levels. Farmers noted that they delayed maintaining equipment or investing in upgrades, which had flow-on effects to the farm support industries [311].

There were several examples of community support during the snowstorm, which were a result of a practised Rural Support network. Kelly and Smith [311] note that farmers in most areas checked on their neighbours immediately following the event and over the following days, spare materials such as camping gear and spare services such as meals and hot showers were offered to those in need [311]. Several different forms of assistance were provided by others in the rural community, including family and friends, farm-support organisations, as well as service organisations; the assistance provided included labour assistance and spare supplies, which included snow raking or removal of dead stock, additional feed and lending spare machinery. There were also examples of assistance to the household, which included babysitting, preparing meals, washing clothes, and providing food parcels. All of these assistance measures were found to support the findings of other rural disaster responses where social capital was used as a hazard mitigation technique [279, 332, 333].

Support organisations played an active role in assisting affected rural organisations, their families, and the rural community. The Ministry of Agriculture and Forestry (MAF), which has subsequently been renamed the Ministry of Primary Industries (MPI), along with the Rural Support Trust (RST) observed the impacts to farms to include stock welfare concerns, loss of feed and feed quality, structural damage to farm infrastructure, lifeline disruptions, and access challenges [131]. MAF and the RST employed snow raking teams, providing electrical generators, and sourcing hay and silage for emergency feed. The snow raking teams recovered over 15,000 livestock while the generators provided power to dairy milking sheds for 1000 cows [131]. The generators were also used to provide heating and feeding for poultry and pigs.

Welfare agencies noted social impacts related to the extended exposure to the event. The losses of critical services and the impassable roading network led to food shortages, and loss of income. The roading conditions also forced schools to close, requiring the caregivers (primarily women) to stay at home to care for children [131]. In response, the welfare agencies deployed teams to gather welfare data on stranded homesteads, provided provisions for those in need, and deployed further personal visits once the road conditions improved to assess the psychosocial needs of the affected families [131].

6.6 The 2010 Southland snowstorm

The Southland region (the southernmost region in New Zealand) has had relatively regular experience with snowstorms. Snowstorms in the region are typically the result of south-westerly airstreams that draw warmer moist air from the Tasman Sea. That said, the most recent major storm events have shown variations in this general pattern. The Southern lowland area can expect snow depths of around 10-15 cm once in every 50 years, while northern and highland areas are expected to see depths approaching 30 cm. The mean westerly component across the Southland region is forecasted with relatively high confidence to increase by approximately 10% over the next 50 years [309]. Since 1995, five severe snow storms have affected the Southland region as summarized in Table 6.1.

The 17-25 September 2010 snowstorm (adverse weather event) was an unseasonably late springtime snowfall followed by wet, below zero conditions across the Southland region. The snowfall occurred as a result of the ideal combination of several factors that, quoting NIWA, "were at the right place at the right time" [334]. Described as a complex low, the system drew very cold air and precipitation from unusually far south in the Southern Ocean, drawing air from as far south as Antarctica with precipitation falling as rain, hail and snow. The very strong cold westerly flow was an unusual direction as most winter as spring storms are more often from the southwest. The majority of snow that fell during the event occurred from 8pm on 17 September to 12pm on 18 September, characterised as wet snow with a very high moisture content and weight capable of collapsing roofs. Snow depths taken in Invercargill's city centre found to be between 12 and 13 cm with a mean density of 380kg/m^3 [334] which is very dense and comparable to the typical density of wind packed snow [335]. While no formalized regional snow depth projections of the event were recorded, anecdotal evidence suggests that snowfall depths were greater along the coastal areas and were progressively deeper eastward from Invercargill, with no snow reported in Winton to depths greater than 30 cm. (1 ft.) in Edendale and 15 cm falling in Invercargill City. Despite the wet snow conditions, some preferential deposition was believed to have occurred in wind sheltered locations [334].

In Invercargill, several organisations closed due to fear of roof collapse due to the weight of the snowfall. EM Southland worked with the Fire Service and Police to conduct building assessments. Of the recorded 56 buildings in Invercargill that were assessed for structural integrity, eight buildings were closed and at least 5 showed some signs of roof damage, including the Southland Stadium. The most commonly damaged buildings were those with flat roofs due to the high snow load and those with internal guttering/spouting due to the ice and rainfall. Examples of the effects of the snowfall during the first two days of the event are illustrated in Figure 6.1.

In days following, the event posed operational challenges to many farming organisations as well as secondary producers. Following the initial snowfall, a cold front brought an extended period of low temperatures, freezing rain, and high winds. Temperatures

Table 6.1: Summary of recent snowstorm experience in Southland.

Date	Description
24-25 September 1995	A slowly moving south-eastern cold front that brought freezing temperatures and precipitation, depositing snow at elevations above 200m. The event was described as unseasonably late, occurring during peak lambing which caused the death of over 50,000 lambs. The event also created hazardous driving conditions that resulted in several accidents and road and school closures. There were also widespread power outages due to downed trees and branches contacting power lines, with repair work delayed up to 18 hours in the more remote areas.
1-4 July 1996	A south-western airflow that deposited between 5 and 30 cm of snow and produced record-low temperatures of -13.4 °C in Invercargill. The snow closed the Invercargill airport and several regional highways. Power lines were damaged from the snowfall, downed trees and limbs. The severe cold froze and burst water pipes which resulted in property damage. In response, taps were often left on overnight to prevent freezing and water consumption rose to extreme levels. Unlike the September event in 1995, stock losses were not found to be a significant problem. The low temperatures did cause diesel fuel to wax or solidify.
2-4 July 1999	A severe northwest gale force wind-storm that brought with it heavy snowfall. The majority of impacts were a result of the high winds. These impacts included uprooted trees, downed power lines, and roofs blown off. Power outages were the most significant result of the event, with some areas without power for 3 days, costing affected businesses in the city of Queenstown (located in Central Otago) up to $300,000.
25-28 May 2002	An extremely cold south-westerly front with daytime temperatures in Gore reaching only 1 °C. The event created snow drifts of 30-40cm that forced some road closures, most notably roads above 300m in elevation. These conditions forced several school closures and caused regional flooding on the 29 th , as the snowmelt caused rivers to overflow their banks.
15-16 August 2004	A cold southerly flow that prevailed for two days, iced over the roading network and deposited snow depths of up to 20 cm. Due to the difficult driving conditions, there were several accidents, regional schools were closed, and public transportation was cancelled. Downed trees and branches caused power outages as well.

Source: [309]

Figure 6.1: Progression of the snowfall event: a) Southland Stadium roof collapse which occurred during the first day of the event. b) Snow cover on the roading network the evening of the 18^{th}. c) Snowfall had largely stopped by the second day of the event. However, consistently low temperatures combined with high winds and freezing rain persisted during the weeks following. Image Source: [336]

during this period were colder in areas of higher elevations; however, the average low apparent temperatures of the region were below zero (apparent temperature is a metric used to estimate felt-temperature devised by Steadman [337] based on a variety of factors including dry-bulb temperature, vapour pressure, wind speed, and sun intensity). The front was orientated in an unusual direction for which the shelterbelts were not properly positioned. This effectively drove stock into depressions and shelterbelts where standing water formed quickly. Many sheep and beef farmers were lambing at the time, and stock losses were widely reported.

The snowstorm event and subsequent cold front were defined as a medium-scale adverse event by the Ministry of Primary Industries, which initiated several predefined assistance measures for farming organisations. A medium-scale adverse event is declared during an event deemed to be infrequent in likelihood, with district or multi-district level physical, economic and social impacts. The assistance measures include (1) rural assistance payments, which are an income and asset tested living expense subsidy program; (2) technology transfer assistance which is a grant program designed to be used towards education workshops, meetings and media releases regarding disseminating best-practice management techniques for the adverse event; (3) community event assistance which is the sponsorship of community events designed to boost morale; (4) the appointment of a recovery facilitator who works closely with the Rural Support Trust in coordinating the recovery operations; (5) labour assistance in the form of a program called Enhanced Task Force Green (ETFG) which provides workers and supervisors to assist in farmers clean-up effort; (6) volunteer costs which in some recovery operations will cover volunteers travel expenses; (7) and funding for Rural Support Trusts during the event to assist in the coordination of the response effort [169].

Rural Support Trusts (RST) are a network of regional organisations designed to provide support to rural people affected by climatic, financial or personal adverse events. The RST, staffed by local community members, are designed to coordinate with affected farmers, the local community, rural support groups, industry groups, the recovery coordinator, civil defence, volunteers, and ETFG. To gather impact data, the RST contacted regional farmers and arranged to drop off small packages of household goods valued at $80 that were intended to help alleviate some of the potential effects of isolation, ensure no affected farms were running short on food, and to gather data on the physical state of the farm and the psychosocial state of the farmer and their family.

The RST also worked in close association with Federated Farmers, the nationwide farmer union and lobby group, to help assist affected farmers by jointly running information meetings designed to disseminate best-practice management options [314]. The Federated Farmers managed the Federated Farmers Recovery Fund, which was a collection of cash donations that approached $1M made by a variety of industry groups and individuals. The Federated Farmers website acted as an information clearinghouse that published information from Inland Revenue, local banks, weather outlooks, feed lists for farms looking to source additional feed, rural contractors and mental health contact information among other support agencies [314]. Other organisations hosted community meetings independently of the RST, often to provide best-practice management advice and provide a social environment intended to decrease stress.

6.7 Methods

For this study, a mixed-methods approach to data collection was used, consisting of a questionnaire-based assessment that was deployed to both farming and non-farming organisations as well as semi-structured interviews with Emergency Management Southland, the Rural Support Trust (Southland), as well as affected organisations. Organisations were classified as either farming or non-farming organisations; organisations that are defined as a primary industry under the ANZSIC classification scheme have been categorized as farming organisations while all other organisational types were designated as non-farming organisations.

To collect a comprehensive listing of farming organisations addresses and contact information, farming organisation addresses and contact details were gathered using a regional farm location map [338]. The sample area consisted of thirteen reference grids, which were 25km by 17.5km and varied in the number of farms per grid, ranging from five farms in the least populated grid to 81 in the most populated. Potential farming organisations were selected by first defining the sample area using the Farm Location Map, which provides a grid reference map of the region. The thirteen reference grids were chosen, which were roughly located between the townships of Winton and Gore extending south towards the coast. All farms listed in the farm address book were separated according to the corresponding grid reference number. Then within each grid reference list, farms were ranked by random assigned values, and selected based on these values. In total, 300 farms were selected to be contacted.

For non-farming organisations, the yellow pages were used as a source in selecting organisations. To ensure that not all organisations were selected from the higher population of Invercargill, the cluster sample selection methodology used was to select 100 organisations from Invercargill, and 50 from each of the smaller rural townships of Winton, Lumsden, Gore and Edendale. Organisations listed in the Yellow Pages in each of these townships were collected, randomly assigned values, and selected based on those random values.

In total, 300 farming organisations and 300 rural non-farming organisations were contacted, employing the methodology defined by Dillman [192]. Organisations were first mailed a hard-copy of the questionnaire, a cover letter explaining the purpose and sponsorship of the questionnaire, and a pre-paid return envelope. The organisations were then contacted by telephone and asked to either complete the questionnaire over the phone or using an online survey engine. Non-farming organisations were contacted weekdays between 10AM and 4PM and farming organisations were contacted between the hours of 5PM and 9PM. Organisations were first contacted in late May and were given 5 weeks to respond to the questionnaire.

The questionnaire (shown in Appendix C) used assessed the disruptive nature of the event by providing different types of damage or disruption (e.g. structural damage, non-structural damage, electricity disruption, communications disruption, stock loss, etc.), asking responding organisations to rank each disruption using a four-point Likert-scale based assessment ranging from not at all disruptive to very disruptive. Basic demographic data, such as age of the organisation, industry type, ownership structure and the number of employees among others, was asked to better categorize the sample set. To assess any factors that may have proved helpful in mitigating the effects of the event, organisations were given a list of potential factors and asked to rank each using a four-point Likert-scale ranking scheme similar to the method used for the disruption factors. Using an open-ended item, organisations were also asked to report the single-greatest challenge faced in the aftermath of the event.

The data collected by the questionnaire was self-reported and collected following the event, and is therefore subject to a range of biases, examples of which may be found in Robson [339]. The perception of the event's impact on each organisation is subject to the bias of the individual responding, which may be influenced by a range of factors. Respondents may view there to be a perceived benefit to over or underreporting the severity of damage incurred by the organisation to potentially garner attention or assistance from relief organisations or to appear less affected to competitors. This variability has been acknowledged in prior studies [111] and there appears to be no evidence to support any systematic bias exists in prior or current results.

The meteorological data used for analysis was from the Virtual Climate Station Network (VCSN) which can be accessed from CliFlo: NIWA's National Climate Database on the Web. The VCSN data are interpolated values of Wind Speed, Maximum and Minimum Temperature, Relative Humidity, MSL Pressure, Potential Evapotranspiration, Soil Moisture, 10cm earth temperature, and Global Solar Radiation, gridded at 5 kilometre resolution. The VCSN data was used because it offers a variety of high-resolution metrics that can be spatially compared to sampled organisations. Apparent temperature, as defined by Steadman [337], was calculated to represent the effective experience during the event. The average apparent temperature from 17 - 25 September and the locations of responding organisations is shown in Figure 6.2.

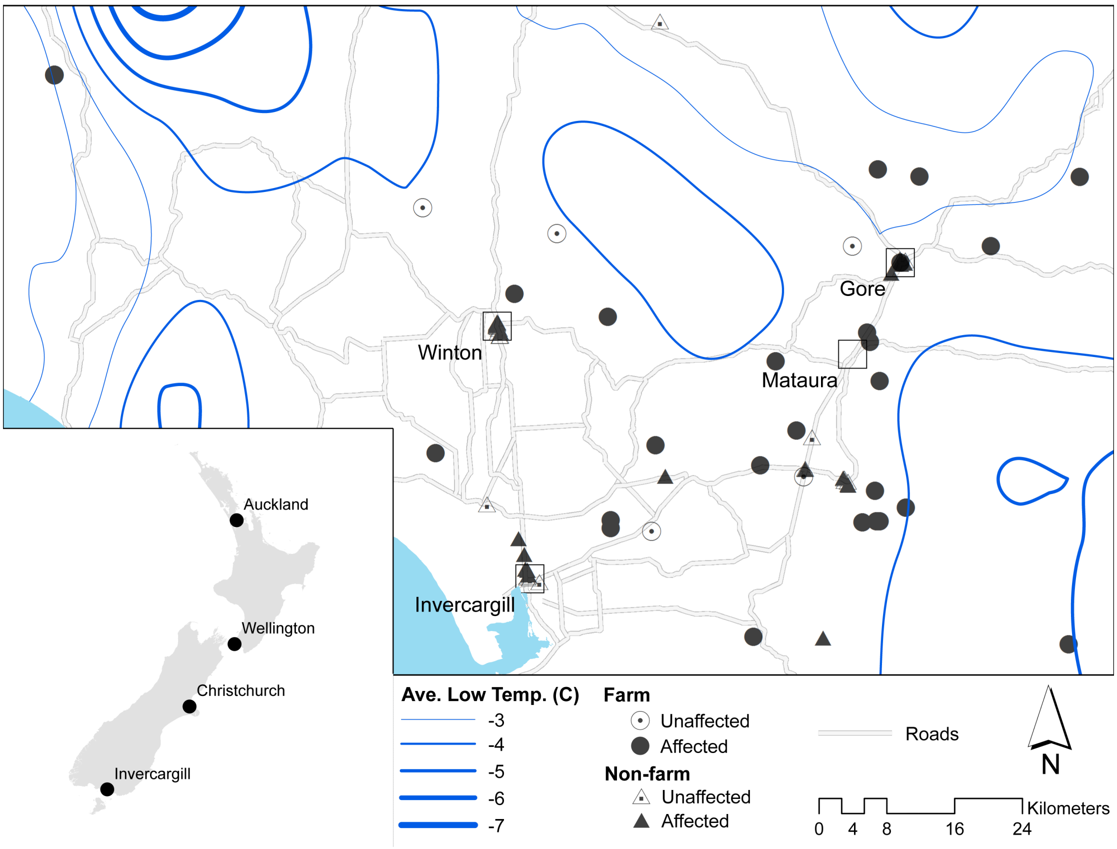

FIGURE 6.2: Sample region with organisation locations and average apparent temperature bands during the event.

6.8 Results

Of the 300 farming organisations contacted, 31 responded to the questionnaire attaining a relatively low response rate of 10%. A better response rate was achieved for the non-farming sample, with 55 of the 300 organisations contacted (18% response rate) electing to respond to the questionnaire. One potential reason for the difference in response rates between the two samples was that the farming sample was far less likely to respond using the online survey engine, and in some cases did not have a computer with a reliable internet connection available at their homestead. Comparatively, the preferred method of replying for the non-farming organisational sample was online.

Farming organisations employed, on average, fewer full time employees than non-farming organisations. The average number of full time employees per farm was 3 with a standard deviation of 5. Comparatively, the non-farming sample group employed an average of 20 employees with a standard deviation of 88. The larger variability within the non-farming

Table 6.2: Sector breakdown of farming and rural non-farming sample sets.

Sample	Sector	N	%
Farm	Arable	2	2%
	Beef	1	1%
	Dairy	8	9%
	Other	2	2%
	Sheep	8	9%
	Sheep and Beef	10	12%
Non-farm	Accommodation and Food Services	2	2%
	Arts and Recreation Services	1	1%
	Construction	4	5%
	Education and Training	3	3%
	Financial and Insurance Services	5	6%
	Health Care and Social Assistance	2	2%
	Information Media and Telecommunications	1	1%
	Manufacturing	7	8%
	Other Agriculture and Fishing Support Services	2	2%
	Other Services	5	6%
	Professional, Scientific and Technical Services	5	6%
	Public Administration and Safety	1	1%
	Retail Trade	14	16%
	Transport, Postal and Warehousing	1	1%
	Wholesale Trade	2	2%
Total	Farm total	31	36%
	Non-farm total	55	64%
	All sectors	86	100%

sample when compared to the farming sample is attributable to the breadth of industry sectors included in this general categorization.

The vast majority of farming organisations sampled (93%) raised some form of livestock. Sheep and beef mixed farming represented 32% of the farms, sheep farming and dairy farming both comprised 29%, while beef, arable, and other types of farming comprised 6% of the sample or less.

The non-farming sample group consisted of 15 different industry sectors. The most common sector in the sample was the retail trade, consisting of 25% of the non-farming sample. Manufacturing was the second most common sector, with 12% of the non-farming sample. The remaining sectors comprised less than 10% of the non-farming sample and a complete list may be found in Table 6.2.

Table 6.3: Farm and rural non-farming organisational reinstatement cost summary. All costs are reported in NZD ($NZD \approx 0.8USD$).

	Farm		Non-farm	
Type of Insurance	N	%	N	%
Cash flow/income protection/org. interruption	7	29%	15	71%
Property and buildings	23	96%	18	86%
Organisation assets and equipment	18	75%	21	100%
Commodities and goods	8	33%	16	76%
Motor vehicles	22	92%	17	81%
Public liability	22	92%	19	90%
Other	10	40%	1	5%

Geographically, non-farming organisations were much more likely to be located within or near the boundaries of a rural township such as Winton, Gore, Edendale, or the city of Invercargill. Farming organisations were more likely to own their land and premises than non-farming organisations. Ninety percent of farms sampled owned the land and premises from which they operate compared to only 56% of non-farming organisations. The farming organisation sample also maintained more structures on the premises when compared to the non-farming sample. The average farming organisation sampled maintained 6 structures while the average non-farming organisation maintained 2. Non-farming organisations on average were in business for longer than the farming organisations and had longer terms of operation at their locations as well. Non-farming organisations were in business for an average of 39 years and had operated at that location for 26 of those years. In contrast, farming organisations on average had been in business for 21 years and had operated at that location for 18 of those years.

In terms of insurance, both farming and non-farming organisations showed relatively high levels of coverage. While non-farming organisations had higher levels and a wider breadth of coverage when compared to farming organisations, farming organisations were similarly likely to hold some form of coverage for property and buildings, public liability, motor vehicle, and organisational assets and goods. Non-farming organisations were much more likely to have cash flow, income protection, or organisational interruption insurance and commodities and goods insurance. A complete summary of the types of insurance held by responding organisations can be found in Table 6.3.

Farming organisations were twice as likely to report being affected by the snowstorm event than non-farming organisations. Furthermore, farming organisations were more likely to close temporarily following the event than non-farming organisations. The

Table 6.4: Summary table of organisational decriptives.

	Farm (N=31)		Non-Farm (N=55)	
Variable	Mean	Std.Dev.	Mean	Std.Dev.
Full-time employees	3	4.9	20	87.8
Years in Business	21	21.1	39	42.8
Years at Location	18	17.3	26	35.5
Number of Structures	6	3.7	2	2.5
	N	%	N	%
% Owned	27	90	31	56
% Affected	25	81	23	42
% Closed temporarily	5	16	5	9
% Closed permanently	1	3	0	0
	%	$\bar{x}\,\Delta$ Rev.	%	$\bar{x}\,\Delta$ Rev.
Revenue Increase	28	17%	22	18%
No Change	28	-	48	-
Revenue Decrease	44	-18%	30	-15%

average duration of temporary closure was 2 days. Farming organisations were more likely to experience decreases in revenue when compared to non-farming organisations. One farm was forced to sell due to bankruptcy and consequently closed permanently. There were no reports of non-farming organisations closing permanently due to the effects of the snowstorm. A summary table of this organisational data may be found in Table 6.4.

6.8.1 Disruptions factors

When asked what factors were found to be disruptive for organisations, two very different pictures emerged between the farming sample and the non-farming sample. For farming organisations, the overwhelming response was with regards to the loss of livestock. Nearly 70% of farming organisations cited losing some stock to the event. For sheep farming, percent estimates of the stock losses averaged between 20 to 30% of lambs and 10 to 20% capital stock (ewes).

Conversely, the most frequently cited disruption recorded for the non-farming organisations was site access. Nearly 50% reported staff having difficultly accessing the worksite. Examples of this can be found in the city of Invercargill for smaller, retail operations

Table 6.5: Factors that were identified as being disruptive by affected organisations.

	Farm		Non-farm	
Disruptive factors	N	%	N	%
Stock Loss	15	68%	0	0%
Other	5	22%	2	9%
Staff can't access the workplace	4	18%	11	48%
Inability to deliver services	3	14%	6	26%
Damage to exterior	3	14%	3	13%
Inability to receive supplies	3	14%	1	9%
Having to clear snow	2	9%	5	23%
Damage to fence, gates, or shelterbelts	2	9%	0	0%
Damage to structure	1	5%	0	0%
Damage to locality	1	5%	0	0%
Disruption of lifelines	1	4%	0	0%
Waiting for damages to be repaired	0	0%	1	5%
Owner had other obligations	0	0%	2	9%

and in the rural township of Edendale for a large industrial milk processing plant. Approximately 20% of non-farming organisations were also disrupted by the inability to deliver services and having to clear snow from the premises. A complete summary of disruptions may be found in Table 6.5.

Sampled organisations were also asked to rate the severity of different disruptions and the differences between the two groups expanded. For farming organisations, the most disruptive elements were either directly or indirectly related to livestock. The loss of livestock was ranked as the most disruptive element, with an average rating across all affected farming organisations to be between moderately disruptive and very disruptive. An inability to access shelter for stock was rated as moderately disruptive. The damage to the ground and/or soil was rated between not very and moderately disruptive, and was largely attributed to livestock forced into shelterbelts and damaging the soil. An inability to access feed for stock was also viewed as either not very to moderately disruptive for most affected farms. A complete summary of the disruptive elements can be found in Table 6.6. Severity was calculated by dividing the maximum value of the 4-point Likert scale response item by the average rating for farming and non-farming organisational sample sets.

While non-farming organisations rated staff's inability to access the worksite as being the most commonly cited disruptive element, the level of disruption this caused to the organisations was rated between not at all to not very disruptive. All remaining disruptive

Table 6.6: The severity of the disruptive factors. Abbrevations used are as follows: dmg. denotes damage; comms. denotes communications; struct. denotes structural; orgs denotes organisations.

	Farm (N=25)			Non-Farm (N=23)	
Rank	Impact	Severity	Rank	Impact	Severity
1	Inventory/stock dmg.	77%	1	Unable to access site	12%
2	No shelter for stock	53%	2	Electricity disruption	10%
3	Damage to ground/soil	39%	3	Staff welfare	9%
4	No feed for stock	31%	4	Struct. dmg. to build.	7%
5	Unable to access site	28%	5	Non-structural dmg.	7%
6	Staff welfare	20%	6	Comms. disruption	4%
7	Electricity disruption	17%	7	Nearby orgs. dmg/close	3%
8	Fence/shelterbelt dmg.	16%	8	Ground/soil dmg.	1%
9	Non-structural dmg.	12%	9	Adjacent orgs dmg.	1%
10	Struct. dmg. to build.	9%	10	Damage to equipment	0%
11	Water supply disruption	7%	11	Inventory/stock dmg	0%
12	Comms. disruption	7%	12	Fence/shelterbelt dmg.	0%
13	Sewage/effluent disrupt	4%	13	No feed for stock	0%
14	Damage to equipment	3%	14	No shelter for stock	0%
15	Adjacent orgs dmg.	1%	15	Water supply disruption	0%
16	Nearby orgs. dmg/close	1%	16	Sewage/effluent disrupt	0%
17	Injury to employees	1%	17	Injury to employees	0%

elements were viewed to be similarly not very disruptive. Only isolated circumstances of very disruptive elements were recorded, with the most notable being structural and non-structural damage to the building. Therefore non-farming organisations were not only less likely to have been affected by the event when compared to farming organisations, the nature of the event was rated as less disruptive.

6.8.2 Greatest challenges

Organisations were also asked in an open-ended question to describe the single greatest challenge about the event. For farming organisations, the responses were highly related to the loss of stock, the amount of time and energy required in attempting to protect the stock from the event, the financial stresses of losing so many stock, and the psychosocial impacts of being unable to help the stock or in having to pick up so many dead stock. The coded responses of farming organisations are shown in Table 6.7. The percent coverage value reflects the number of words related to the coded construct as transcribed from the farmers' responses.

Table 6.7: Coded response summary of farming organisations greatest challenges. As not all organisations chose to respond and consequently the variable does not total to 100%.

Challenge	Percentage coverage
Stock Loss	22%
Stock Management	16%
Financial	15%
Psychosocial	12%
No Challenge	6%
Increased workload	6%
Planning for future events	5%
Isolation	3%
Pasture Management	3%
Business Management	2%
Customer Issues	1%

Table 6.8: Correlations between farming organisational greatest challenges responses in terms of word choice similarity.

Challenge A	Challenge B	Pears. corr. coeff.
Psychosocial	Increased workload	0.84**
Stock Loss	Increased workload	0.43*
Stock Loss	Psychosocial	0.27
Stock Management	Stock Loss	0.25
Financial	Customer Issues	0.23
Stock Loss	Financial	0.22
Stock Management	Business Management	0.2
Psychosocial	Isolation	0.17

** denotes p≤0.01 (2-tailed); * denotes p≤0.05 (2-tailed)

The most commonly cited challenges showed some interrelationships between one another. Assessed using Pearson product-moment correlation coefficient as a control against the small sample size, the strongest association between two challenges was found to be between psychosocial impacts and the increased workload (Pearson Corr. Coefficient = 0.84). The second strongest association was found between stock loss and increased workload (Pears. Corr. Coeff. = 0.43). A complete summary of the associations between farming greatest challenges can be found in Table 6.8.

6.8.2.1 Psychosocial challenges

For farming organisations, the associations between the psychosocial impacts and livestock losses to increased workload illustrate the challenges farmers faced in attempting to save their stock despite having very few options available to them, and ultimately being forced to suffer major losses. Examples from the written responses of farming organisations' summarizing their greatest challenges are as follows:

1. "Getting around and picking up all the dead stock. Picking up 800 dead lambs."
2. "Biggest challenge during the event was animal and human welfare. Afterwards [was the] financial strain. Significant stress."
3. "Getting back to normal, staff back to normal, getting them rested, paying for extra feed. Neighbours talking [was] really helpful."

The first quote summarizes the direct relationship between the stock loss and increased workload. In several interviews, farmers cited having evenings of 100% lambing losses. A commonly cited practice to mitigate lambing losses was to shelter stock indoors. However, the region does not winter stock indoors, and therefore only a certain number of the livestock could be sheltered at any one time, forcing the farmer to constantly rotate stock. Between the combination of the snow cover and sheltering stock indoors, there was an elevated risk of diseases such as milk-fever (postparturient hypocalcemia, or parturient paresis) or sleepy sickness for capital stock (pregnancy toxaemia), which are potentially fatal illnesses that can stem from changes in diet or diet restrictions. Several farmers cited at least some stock contracting the diseases.

The second quote reflects a general summary of the event's psychosocial, physical and financial challenges. The third quote reflects not only the impact of extreme workloads, but also notes the relief found in discussing the event with their neighbour. Results from semi-structured interviews align with these results as farmers frequently cited experiencing feelings of extreme exhaustion from long working hours, helplessness during the event in watching their stock suffer, and stress due to the financial losses from stock loss. Some farmers noted that prior storm events had typically lasted up to three days, and by the last day it was clear the weather would improve. However in this case, the eight day duration of the event provided a sense of distress which was summarized by the following quote from an affected farmer: "[The] weather forecast was just dire. There was no glimmer of hope."

Despite the psychosocial impacts of the event recognized as one of the greatest challenges of the event for farming organisations, no farms sampled sought the assistance of a

Table 6.9: Coded response summary of non-farming organisations' greatest challenges. Percent coverage reflects the number of words dedicated to the coded construct. As not all organisations chose to respond and consequently the variable does not total to 100%.

Challenge	Percentage coverage
Customer Issues	23%
Decreased Customer Spending	13%
Financial	7%
No Challenge	4%
Staff Management	3%
Forecasting	2%
Increased Demand	2%
Prepare for future events	2%
Supply Issues	2%
Advertising	1%

mental health professional. However, farmers did cite the mental health advice reported through media outlets to be helpful. A majority of farmers (65%) cited the information to be helpful compared to 44% amongst rural non-farming organisations. Only 18% ($N = 4$) of farms cited the mental health information disseminated at farm meeting events to be helpful. Of those 4, three farms stated the reason the meetings were helpful was not necessarily because of the information, but rather because the meeting was an opportunity to socialize with others.

6.8.2.2 Customer issues

The greatest challenge for non-farming organisations were related to issues with their customers. While rural non-farming organisations largely reported not being very disrupted by the direct effects of the event, the greatest challenge reported illustrated that the event did directly impact their clientele heavily and consequently created changes in customer behaviour. A summary table of the greatest challenges can be found in Table 6.9.

In most cases, customers were either less likely to make purchases, needed additional time or credit, or decreased the amount usually spent, all of which had financial consequences for the non-farming organisations. This existed across sectors that directly deal with processing farming outputs, as well as those that service all local clientele. From an interview conducted with a local freezing works operation, the major effects reported were lower levels of production following the event due to a lack of available supply and consequently less profitability; the overall drop in throughput was estimated at 600,000 lambs, with a flatter season, a later kill and a drain on cash flow. Farmers reported holding back stock in response to stunted growth and the high and continually rising commodity prices provided some incentive to hold back stock. It was estimated by the freezing works operation that sheep farming organisations lost approximately 20% of lambing stock, and held back surviving stock, which decreased the regional supply of stock available for freezing works significantly. The freezing works operation noted that stock were somewhat smaller than usual but the weights have been fine and there were no major issues with the quality of stock. The freezing works operation also expected the lamb population to rebound in the following season despite the ewe (capital stock) losses.

The impacts also extended to farm suppliers. A farm service provider observed sales on non-essential items had dropped approximately 30-35%, noting that over the previous year's these sales had been extremely consistent and this drop was highly irregular. In most cases, non-farming organisations cited some issues with their customers or supply chain. In general, the majority of non-farming organisational challenges can be summarized by the following examples:

1. "[The] biggest challenges have generally NOT been snowstorm related, but indirectly locals not spending as much."
2. "A lot less lambs to process."
3. "Two to three weeks quiet in the shop due to farmers dealing with their own situations at their farms."
4. "It has been more difficult to sell extra or add on services to our clients. Some clients have gone without some of the services they would normal have. Some every 5/6 weekly clients are stretching appointments out to the 6/7 weekly which means less visits to the salon annually. Clients also have sought more low maintenance forms of colouring so as to get by longer."

The customer issues, decreased customer spending, staff management issues, and financial challenges showed relatively consistent levels of association. Staff management

Table 6.10: Correlations between greatest challenges of non-farming organisational responses in terms of word choice similarity.

Challenge A	Challenge B	Pears. corr. coeff.
Decreased Customer Spending	Customer Issues	0.54**
Staff Management	Financial	0.45*
Financial	Customer Issues	0.42*
Financial	Decreased Customer Spending	0.18

** denotes p≤0.01 (2-tailed); * denotes p≤0.05 (2-tailed)

issues were, in some circumstances directly related to customer issues. For example, immediately following the initial snowfall, there was the challenge of finding staff capable of accessing the worksite. However, over the course of the weeks following the event when customer numbers or spending decreased, owners noted that they had more staff on-hand than were necessary. A summary of the correlations between challenges can be found in Table 6.10.

One exception to these general findings of decreased customer numbers or demand for services, was for the slink skin organisations that remove dead stock, typically during an eight-week period resulting from the natural death of newborn animals. From interviews conducted with a local slink skin operation, the snowstorm occurred during this eight-week period where the business at capacity with the typical 10% newborn loss rates, which ballooned to approximately 50% during the event. The organisation cited being unprepared to deal with such a large influx of product, much of which had deteriorated to an unusable state by pick-up due to the weather conditions, the additional time required by the slink skin to scale up to meet demand and the longer travel time required in the difficult road conditions. Ultimately, the slink skin operator feared the storm would further depress the stock numbers in the region, leading to lower output and product availability for processing in the following season.

6.8.3 Mitigating factors

To determine what factors helped mitigate the impacts of the event, organisations were asked to rate the helpfulness of different factors on a four-point Likert scale, with 0 equal to not at all helpful and 3 equal to very helpful. The results were then divided by the maximum score of three, averaged across farming and non-farming sample sets and presented as a percentage. As shown in Table 6.11, the most helpful factors for non-farming

Table 6.11: Factors helpful in mitigating the effects of the event for both farming and non-farming organisations.

	Farm (N=25)				Non-farm (N=22)		
	Factor	Mean	%		Factor	Mean	%
1	Commodity prices	2.2	75%	1	Well-built buildings	2.2	73%
2	Well-built buildings	2.1	71%	2	Staff	1.8	59%
3	Working lifelines	2.1	69%	3	Working lifelines	1.5	51%
4	Neighbours	1.9	63%	4	Suppliers	1.1	38%
5	Cash or credit	1.4	48%	5	Emerg. MGMT plans	1	35%
6	External resources	1.4	47%	6	Cash or credit	1	33%
7	Staff	1.4	45%	7	Commodity prices	0.8	26%
8	Suppliers	1.2	41%	8	Emergency kits	0.7	24%
9	Banks	1.2	40%	9	Prac. emerg. response	0.6	20%
10	Industry orgs.	1.2	40%	10	Neighbours	0.6	20%
11	Manager	0.8	28%	11	Manager	0.5	18%
12	Lifeline alternatives	0.5	16%	12	Banks	0.4	12%
13	Insurance	0.4	15%	13	External resources	0.4	12%
14	Prac. emerg. response	0.4	13%	14	Other	0.3	11%
15	Emerg. MGMT. plans	0.3	11%	15	Alternative sites	0.2	8%
16	Emergency kits	0.1	4%	16	Lifeline alternatives	0.2	6%
17	Alternative sites	0.1	3%	17	Insurance	0.2	6%

organisations were well-built buildings, staff, and uninterrupted critical services, which was most notably electricity. Factors that proved moderately helpful were suppliers, emergency management plans, and available cash or credit. Comparatively, farming organisations found a wider variety of factors helpful. The most helpful factors were, in decreasing order, increasing or high commodity prices following the event, well-built buildings, uninterrupted critical services, and neighbours. All of these factors averaged between moderately and very helpful for affected farms. In addition however, several other factors proved to be at least moderately helpful. These include available cash or credit, trade or industry resources, staff, suppliers, banks and industry organisations.

For farming organisations, the increase in commodity prices following the event played the most significant role in mitigating the effects of the event. Immediately following the event, 20-30% stock losses of 1000 head herd sizes could equate to $30,000 in revenue losses or greater. Furthermore, the event stunted the growth rate of the surviving lambs, meaning lambs must be held longer to increase weight. Capital stock losses of approximately 10% were also very costly, and decreased the already depressed herd sizes in the region.

The increases in the commodity prices largely compensated for farming losses. Using the ANZ commodity price index [340–349] as a generalized indicator of the strength of commodity prices for the sheep, sheep and beef, or mixed farming sectors and the dairy farming sectors, at the time of the event the commodity prices for meat, skins, and wool were at $225. By the beginning of spring 2011, which is a time when sheep farmers largely rely on wool prices as a means of cash flow, the commodity prices had risen to $256 and by the end of spring, the price had risen further to $285. Over the summer months, these prices stabilized, remaining high. As a point of comparison, the commodity prices were approximately $100 lower at the same time of the previous year. Estimates from MAF [350] found that despite lambing losses of 20% for the Southland/Otago region, net cash income increased by 29%. The rise in commodity prices was also observed for dairy products, with the increases following comparable gains to meat, skins and wool. The commodity price increases are illustrated in Figure 6.3.

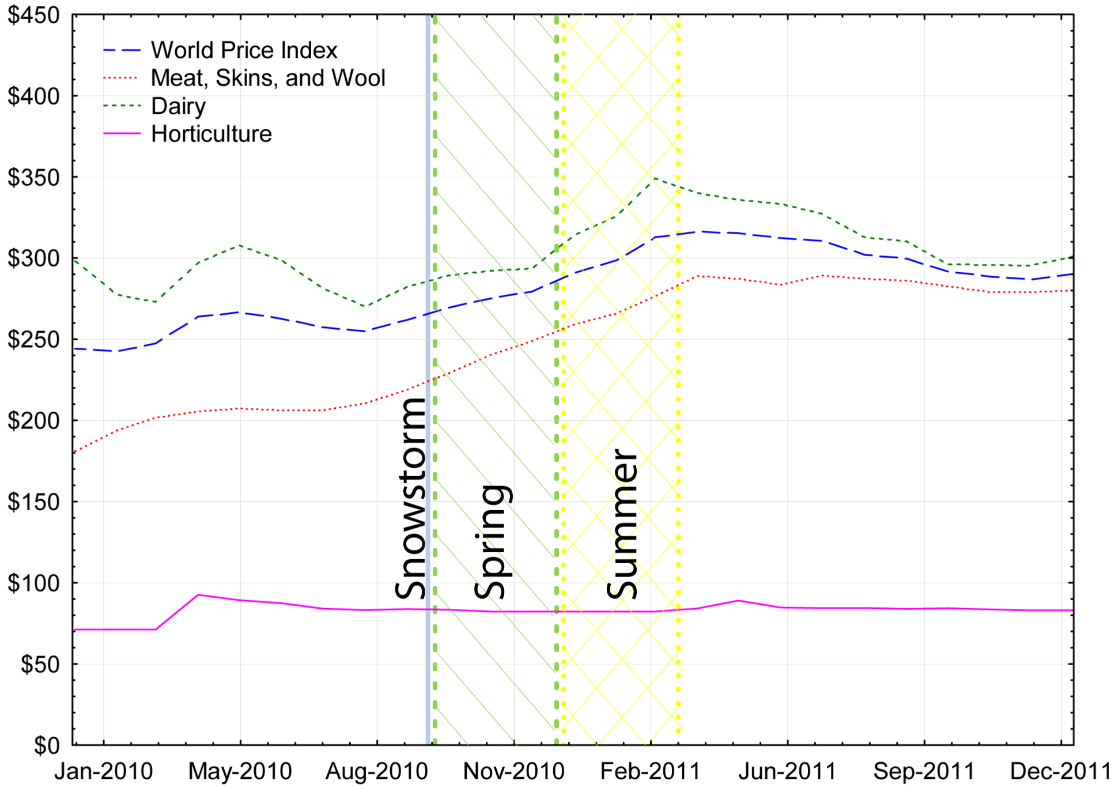

FIGURE 6.3: ANZ Commodity Price Index from 2010-2012 which illustrates the increase in prices following the snowstorm event.

During interviews with affected farmers and finance organisations, there were several mentions of farmers considering exiting in the year following due to the extreme losses or organisational insolvency. The rise in commodity prices “changed everything”, and some farms that experienced 30% stock losses were able to turn a profit, with some electing to pay down their loans.

Well-built buildings were demonstrably helpful for both the farming and non-farming samples. In the farming sample there were no reports of structural failure due to snow loading. Building collapse had proved to be very disruptive in previous snowstorms. However in this circumstance, the prolonged low temperatures and freezing rain that persisted after the initial snowfall were the major challenges. The snow levels were relatively low in comparison to the snow depths in the 2006 Canterbury snowstorm and therefore most damage incurred to structural assets was primarily relegated to non-structural elements such as drainage spouting. All structural damage reports were from organisations in Invercargill where the snowfall was the highest. Those organisations that suffered from structural damage cited the interruption to be very disruptive.

Uninterrupted electrical, telecommunications and water services were also helpful for both farming and non-farming samples. For farming organisations, uninterrupted services was cited as being very helpful in not only assisting in mitigating the direct effects of the event but also in decreasing the feelings of isolation brought on by telecommunication disruptions. Non-farming organisations were largely capable of operating provided staff were able to travel into work and the roading network was largely manageable after 3 days.

Neighbours proved to be a major asset for farming organisations following the event. Farmers reported checking in on one-another often, lending additional labour and services where possible. One key role neighbours played in recovering from the impacts came in the form of labour exchanges in picking up dead stock. Due to the psychosocial trauma of picking up their own dead stock, farmers found it better to pick up their neighbours dead stock as they had no emotional attachment to those animals. In interviews, farmers found this arrangement to be less stressful and when the dead stock were removed from the property, the farmers noted their mood improved, often being quoted as saying: "out of sight, out of mind." In contrast, there was very little evidence of neighbour support being helpful for rural non-farming organisations in the aftermath of the event. Those rural non-farming organisations that did cite neighbour relationships to be helpful referred to the type of support to be emotional.

In terms of suppliers, there was only one instance of a supplier being incapable of providing services, while the majority of all organisations sampled noted that their suppliers were completely capable of meeting their needs. For farming organisations, 84% cited their suppliers to be completely capable, 12% were somewhat capable, and 4% (1 instance), were found to be completely incapable. 2 farming organisations (8%) sought the services of additional suppliers as a result of the snowstorm. For rural non-farming organisations, suppliers were either completely capable (70%), or at least somewhat capable (30%). There were no instances of suppliers being completely incapable of delivering services. Only one rural non-farming organisation (4%) sought the services of an additional supplier.

Insurance was not cited as being a very helpful factor in mitigating the effects of the event, this is because the major impacts of the event were largely not insurable. Farming organisations were primarily satisfied with their insurers, with 73% either satisfied or very satisfied, 22% having neutral feelings, and only 1 affected farming organisation was dissatisfied. The level of coverage provided by insurers met the expectations of the affected farmers. All affected farms reported feelings that were neutral (52%), satisfied (13%), or very satisfied (35%) with the coverage provided. Importantly, the loss of stock was uninsurable prior to the event. Following the event, one insurance provider initiated a stock loss insurance option which would cover stock death from weather. When affected farms were asked whether they would be interested in this type of coverage, there was a mixed response. While several noted the coverage would be helpful in a similar weather event, they also noted it would be an additional expense they felt would be unnecessary and best-practice farm management would serve to mitigate the risk in a more cost-effective manner.

Similarly, the majority of rural non-farming organisations were also satisfied with their relationship with insurers. Specifically, 59% were either satisfied or very satisfied while the remaining 41% had neutral feelings towards their insurer. The level of coverage provided by insurers met the expectations of the affected non-farming organisations. The affected organisations reported feelings that were neutral (77%), satisfied (14%), or very satisfied (9%) with the coverage provided. In the sample group there were limited instances of structural and non-structural damage, and therefore insurance did help mitigate the effects of the event for

TABLE 6.12: Means of financing the recovery for both farming and non-farming organisations.

	Farm (N=25)		Non-farm (N=23)	
	N	%	N	%
Cash flow	13	52%	13	57%
Organisational Savings	2	8%	2	9%
Borrow from family or friends	1	4%	1	4%
Bank Loan	3	12%	3	13%
Credit Cards	0	0%	0	0%
Insurance	1	4%	1	4%
Other	2	8%	3	13%

Both farming and non-farming organisations relied on similar means to finance the recovery. Both samples most frequently relied on organisational cash flow to finance their recovery, and interestingly, bank loans were the second most common means of finance. However, bank loans and other means of finance were only utilized in less than 13% of either sample. A complete breakdown of means of financial recovery sources can be found in Table 6.12.

To finance their recovery, the majority of farmers opted to rely on organisational cash flow. Available cash or credit proved helpful for farming organisations largely in sourcing supplemental feed for the livestock. Additional feed needed to be sourced quickly and in some cases sourcing additional feed proved difficult due to the time of year as local reserves of feed were exhausted and the supplemental feed had to be shipped from sources in Christchurch. However by the time the feed arrived in Southland, the demand had largely returned to the normally low levels for the time of year as the snow melted. Furthermore, due to the high stock losses, farmers now had excess feed reserves in paddock growth.

Some raised capital by selling feed which was available for sale due to the drops in their own stock numbers and holding stock back to add weight. Three farms (12%) sought a loan from their bank to replace stock losses or to diversify their revenue streams by purchasing different types of livestock. In interviews with regional banks, loans were highly considered immediately following the event. But as the commodity prices continued to increase, the interest in taking out additional loans decreased substantially. The diversification options were purchasing stall lambs, cattle, or adding crop. Some farmers utilized their cash flow to diversify as well. In one case, the refusal of additional lending forced a farm to sell out of bankruptcy.

The most common challenge to non-farming organisations came in the form of decreased customer numbers and employees unable to reach the premises. The losses incurred on the days where the business was either closed or during the weeks following where customer numbers and demand for additional, non-essential items decreased. Staff were cited as helpful in mitigating the costs by accepting leave without pay or decreased hours to accommodate for the losses in productivity. These losses were also most aptly covered through organisational cash flow.

6.8.4 The effect on Southland livestock numbers and financial trends

In Southland there has been a significant decrease in the number of sheep numbers and a significant increase in dairy cattle numbers since the 1990s, with the number of beef cattle remaining relatively stable. The total number of sheep regionally has gone from 55,000 in 1991 to below 35,000 in 2011 [247, 351]. Conversely, the number of dairy cattle has nearly doubled, increasing from approximately 3,000 in 1991 to over 6,000 in 2011 [351]. This trend is believed to be attributable to the comparatively high levels of profitability possible in the dairy industry currently and the lower margins available in the sheep market (RST personal communication, 18 September 2010).

The stock losses reported by the RST and the results of this survey are corroborated by data collected by the Lamb and Beef New Zealand survey that showed the lambing rates in Southland and Otago during the 2010-2011 season to be a statistically low outlier when compared to the nine previous years, using Grubbs test for outliers [352]. The mean lambing percentage reported from Southland and Otago from the 2003 to 2009 seasons were 130, which is within the nominal range of 100 to 150 (a percentage of 100 is indicative of difficult conditions capable of supporting only one lamb per ewe while 150 is indicative of a well-fed environment capable of supporting twins and triplets). In 2010, the lambing rate dropped to a statistical outlier of 119 (Grubb's Test: $G = 2.4385$, $U = 0.2659$, $p - value = 0.01$). Calving and fawning rates showed no significant decreases during the 2010-2011 season.

Despite the significant drop in lambing rates, several financial indicators from the region were anomalously high for the 2010-2011 and 2011-2012. The farm surplus measured by the dollar value per stock unit for the two seasons were \$30.33 and \$37.24 respectively, the highest value per stock in the dataset and statistical outliers (Grubbs test for two outliers: $U = 0.1513$, $p-value = 0.01$). Earnings before interest, tax and rent per stock unit for the 2010-2011 and 2011-2012 seasons were \$56.23 and \$63.06 respectively and also outliers in the dataset (Grubbs test for two outliers:$U = 0.2327$, $p - value = 0.05$). The rate of return on total farm capital percentage for 2010-2011 and 2011-2012 were also high, at 2.2% and 2.8% respectively, but may not be considered outliers as these data tend to show greater yearly fluctuations than other financial metrics in the set (Grubbs test for two outliers: $U = 0.2813$, $p - value = 0.1$). These results support the findings of Section 6.8.3, which state that affected farmers identified the increase in commodity prices as being the most helpful factor in mitigating the effects of the event.

6.8.5 The findings of the Rural Support Trust and other support organisations

During and following the snowstorm, the RST organised volunteers to deliver aid packages to regional farms and conduct a semi-structured interview as a means to gather impact data and assess the psychosocial state of the affected rural families. The volunteers were primarily from the major farm-support organisations which included suppliers, industry organisations, co-ops, banks and insurers, many of which had pre-existing relationships or clientele in the region. The approximate cost of each package was \$80 which was funded by donations. The RST explained the packages were used to conduct a semi-structured interview with the farmers. In several cases, both affected farmers and the RST reported that the farmers preferred to simply discuss their experiences and refused accepting the package.

The semi-structured interview questions allowed for a general triage assessment to be made by the interviewer, using a four-point scale of severity. Triage assessments were based on the results of the interview, whether or not the family had sustained some form of personal trauma, and the severity of the stock losses. The highest stock loss rates observed by the Rural Support Trust interview process reached 50 percent, however the more common stock loss rates were between 20 to 30%. Once the results were collected, the cases deemed most severe were contacted by phone and followed up with additional personal package deliveries. Serious cases were directed to a primary health organisation and typically received personal visits from a RST representative for two-weeks following the event. The most serious cases required attention into late December.

Based on the initial triage, pre-existing conditions were identified as a common cause for being considered serious cases, with many of the conditions only exacerbated by the snow. Rural Assistance Payments, which are an assistance program that provides $320 per week for personal expenses, were offered to affected farms but had relatively low uptake rates. The low uptake rates were due to the stigmatization of the assistance programs as a government hand-out and the RST found that getting farms to accept the support challenging. Anecdotal evidence from the RST found that women were more likely to accept the assistance.

The most common finding made by the RST was that farmers espoused a feeling of helplessness during and immediately following the event. Farmers felt a significant emotional toll in being unable to help while having to watch their stock die. Interviews with regional banks expanded on this point, stating that farmers often felt feelings of guilt, with many farmers being quoted as saying "Could I have done more?". There was a need for volunteers to help remove the remains of dead stock; affected farmers were more comfortable in picking up the neighbouring farmer's stock, but not their own. In a response to this, the RST instituted a dead-stock removal service by coordinating volunteers. The RST observed that once the dead livestock were removed, the farmers reported their mental state to be greatly improved.

The findings of the RST were in alignment with the findings of this study during interviews conducted with affected farmers; it was repeatedly noted that the packages organised and delivered by the Rural Support Trust (RST) members or volunteers to be helpful, with respondents often stating that they were "very grateful" for the concern. Importantly, the contents of the package were not considered to be the most valued asset. Instead, most respondents noted that it was the personal contact and the RST's consideration that was most helpful about the package delivery. In one case, the farmer felt the resources used to purchase the package contents could have been better spent elsewhere. There was another instance where the farmer did not receive a visit or a telephone call from the RST. The farmer was aware of the phone calls and visits being conducted by the RST, noting that "...the RST said they had been to every area. There are people that you've (the RST) missed." The farmer noted that being overlooked was "hurtful" and felt "extremely isolated" as a result.

Interviews with the RST and Federated Farmers regarding their co-hosted meetings with the support of banking organisations and support organisations such as Rural Women during three weeks following the event indicated they were disappointed with the turnout. The low turnout was because the worst affected farmers were still recovering from the event and were unable to attend. However it was noted that neighbours played an important role in disseminating the information to those who were unable to attend. Based on these experiences, potential additional methods of communication, such as initiating a mail drop, should be considered in future events. One method that would likely not be effective is through any online medium such as email.

The disbursement of the Federated Farmers Recovery funds proved difficult and a fair methodological use of these funds proved impossible. Of the $900,000 of donated funds, only $300,000 was spent. The primary use of these funds was directed towards the RST initiative of aid packages to affected farms. The goal behind the aid packages was not specifically to deliver goods but rather as a means to approach farms and assess the level of impact on-farm physically and emotionally. Agents were used to deliver the packages as many had pre-existing relationships with the affected farms. One of the major logistical challenges in dealing with equitable disbursements was that several of the trustees hoped their donations to be directed towards specific ends that would benefit their industry. There were also logistical limitations with maintaining up-to-date supply information on the feed list. After two or three days the feed list became out of date and consequently ineffectual after that time. Furthermore, the expectations of what the feed list was were not clearly understood as there were several instances where farmers who contacted the feed list believed the feed was either provided at no charge or subsidized by the recovery funds.

6.9 Discussion

The 2010 snowstorm was more disruptive for farming organisations than for non-farming organisations, primarily because of the livestock deaths or decreases in production. The livestock losses were largely a function of the unseasonably late timing of the event, the extended period of low temperatures, wet conditions, and the unusual storm direction which rendered the shelterbelts ineffectual. The single most helpful factor in mitigating farming losses was the dramatic rise in commodity prices, which compensated for much of the losses through the increased profitability.

The storm's late timing, duration, consistent precipitation and near freezing temperatures created very dangerous conditions for livestock. The unusual storm direction drove stock into shelterbelts or depressions where the ground was quickly saturated and lambs were often dropped in standing water. Shelterbelts were largely ineffectual due to the unusual direction of the storm and the consequent lambing losses were supportive of the findings of Pollard [328, 329]. Similar to the findings of Clark et al. [331], in cases where snow cover was significant or stock were moved indoors for a period of time, the loss of feed access to lambing ewes increased the risk of sleeping sickness (a potentially fatal disease that threatens ewes). Stock management created tremendous workloads for farmers, who were forced to consistently rotate stock through sheds, to most effectively balance the risk of the exposure to weather with the risk of sleeping sickness.

For sheep farming, affected farmers most commonly reported losing approximately 20 to 30 per cent of their incoming lambs, and 10 per cent of ewes or capital stock. Furthermore, the lambs that did survive the event were tracking below weight. The event also had long-term impacts as their capacity to generate stock with their capital stock significantly decreased. For dairy farming, the event flattened yearly production curves for the year, ultimately decreasing production and gross revenue. However, dairy livestock losses were not reported.

Many of the challenges found by Smith [130], Wilson et al. [131], and Kelly [311] during the 2006 Canterbury snowstorm were consistent to the challenges observed in this study. The extreme workloads combined with difficult working conditions created high levels of fatigue amongst the farming organisations sampled. The stress was a product of stock losses, financial worries, feelings of helplessness, the effects of isolation, the extreme workloads and general fatigue.

A major point of distinction between the impacts of the 2006 Canterbury snowstorm and the 2010 Southland snowstorm was the high rates of lambing and capital stock losses. These deaths were especially challenging for the farmers, both emotionally and financially. The emotional attachments to the animals made removing the dead stock very difficult. The substantial decreases in production were sufficient to prompt many farmers into considering exiting from the industry.

Because there were relatively limited power or communication outages during the event, the effect of isolation was a direct product of the intense workload and not an inability to travel on roads or communicate. There was also evidence to suggest that feelings of isolation were increased if support organisations did not contact an affected farmer while having claimed to have contacted all affected farms. The frequency to which farmers cited experiencing feelings of isolation may have been lower than what was reported in Smith [130] or Wilson et al. [131], however due to methodology differences a direct comparison is not possible. In addition, only one member of the household completed the questionnaire and no data was collected on the state of the farmer's spouse or family members.

The single most significant mitigating factor for farms that experienced stock loss was the dramatic rise of commodity prices following the event. While losses due to the event were regionally significant, the drop in supply did not cause the rise in commodity prices. So while market volatility proved significantly helpful in this circumstance, if the commodity prices were to decrease following a similar event, it is likely that a large number of farmers would have exited the industry as a result. These exits would also have very significant implications for the local non-farming industries.

Similar to the results of Kelly and Smith [311] and Wilson et al. [131], informal support networks and governmentally sponsored support initiatives proved helpful in mitigating the effects of the 2010 Southland snowstorm. Neighbours were helpful in providing labour assistance as well as psychosocial support and the package deliveries led by the RST were cited as very helpful factors. Farmers noted that discussing their experiences with either their neighbours, or the representatives sent by the RST helped in decreasing stress levels, which is critically important as farmers showed little interest in seeking assistance from mental health professionals. In terms of labour support, once dead stock were removed farmers noted that stress levels immediately decreased, and any efforts that assist in the removal of dead stock may yield positive mental health benefits. While the RST package delivery system was widely successful, it is important to note that farmers that were not contacted by the RST experienced a sense of isolation and increased stress levels.

As equitable disbursement of the $900,000 in donated funds proved to be challenging, the logistics of a variety of post-disaster initiatives should be developed in peacetime so that in the case of a future event, potential options will have already been developed. In developing these programs, consideration should be given to whether the program will be equitably deployed or if it will unfairly benefit a specific subset of affected farming organisations. Furthermore, the initiatives developed should be made publicly available so individuals or organisations that wish to donate to the relief will know how the funds will be used.

The role of insurance was notably absent in the recovery options available to farmers, specifically because packages covering stock deaths due to inclement weather were not available prior to the event. Although one insurance provider developed and actively promoted a stock-insurance plan following the event, the plan was largely deemed by farmers to be too expensive given the likelihood of another event occurring. However, NIWA predicts that the mean westerly component across the Southland region will increase by approximately 10% over the next 50 years [334]. One of the most problematic features of the snowstorm, aside from the timing, was the westerly direction which rendered the regional shelterbelts ineffective. Therefore, regional farms may want to consider expanding the directional coverage of shelterbelts, or investigating options to offset livestock options in the case of similar weather circumstances.

The interdependent nature of rural economies as described by Edwards et al. [18] and by Pritchard et al. [246] was also reflected in the challenges cited by non-farming organisations. Although the overall impacts of the snowstorm to non-farming organisations were relatively less severe, there were several different examples of flow-on effects which included decreases in raw material supplies, decreased customer numbers, and decreased spending on non-essential items in the months following the event. The direct financial impact to the local non-farming organisations supports the findings of Pritchard et al. [246] who found farming organisations to prefer local procurement of services or maintenance purchases. Additionally in a post-disaster setting, non-farming organisations lose business due to farm spending decreases to preserve cash flow and available capital.

6.10 Conclusions

This chapter finds that the 2010 Southland snowstorm illustrated several similarities to the 1992 Canterbury snowstorm and the 1995 Southland snowstorm largely due to the late timing of the events. The vulnerability of livestock farming in Southland to snowstorms during lambing is the most significant controlling factor in terms of the snowstorms impact. The impacts threatened the viability of several affected farms, and yet the single greatest mitigating factor to these impacts was the international commodities market, an independent variable which is outside the control of the affected farmers. Consequently while the overall impact of the event was limited, the event should serve as a reminder to the dependency of New Zealand's farming industries and rural organisations on the international commodities market.

6.11 Acknowledgements

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Chapter 7

Discussion and future research

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Through the use of several theoretical frameworks, this thesis has identified and compared the impacts of a major earthquake event on farming and rural non-farming organisations, while also contextualizing these impacts with a more typically analysed meteorological event. It has outlined the short-term impacts and recovery strategies of farming and rural non-farming organisations to the Darfield earthquake (Chapter 3), the evolution of those impacts and responses over the course of the Canterbury earthquake sequence (Chapter 4), the financial implications of the Canterbury earthquake sequence for affected farming and rural non-farming organisations (Chapter 5), and the impacts of a major snowstorm in the Southland region of New Zealand (Chapter 6). The comparison of the two distinct natural hazards on rural organisations has also shown that despite the difference in the perturbations, the use of social capital – particularly for farming organisations – was a commonly adopted approach to mitigating the effects of the event.

Additionally, this thesis has demonstrated that the questionnaires discussed in Chapters 3-6 can collect impact and recovery data from two different events, with the caveat that context-specific deployment approaches are used, as described in Chapter 2. Furthermore, this thesis has demonstrated that questionnaire-based short and medium-term disruption metrics can estimate the impacts of an event and investigate relationships between geophysical variables (e.g. OII shown in Equation 3.1), and that high-level repair cost-estimates for farming organisations can be derived from an area given the felt-intensity of the earthquake, the total area farmed per organisation, and the number of employees per organisation (e.g. TARC shown in Equation 5.2). In Appendix A, the differences between the impacts on farming, rural non-farming organisations, and organisations from a wide range of industry sectors in Christchurch is explored. Finally, this thesis has demonstrated that the short-form version of the organisational resilience quantification methodology developed by [78] (as shown in Appendix B) can be integrated within questionnaires designed to capture organisational disruption and mitigating strategy data immediately following the event.

This final chapter summarizes the major findings of the thesis. It begins with a discussion of the data collection methodologies, and follows with a comparative analysis of the Canterbury earthquake sequence and Southland snowstorm events through the consideration of short and medium-term impacts through a variety of theoretical lens (engineering and ecological resilience, vulnerablity, and disaster risk reduction), and the mitigating strategies adopted by affected organisations. Following these comparisons, this chapter proposes a series of factors relevant when considering the impacts of natural disasters on farming and rural non-farming organisations, and makes policy recommendations aimed at increasing rural organisational resilience. Finally, the opportunities for future work are briefly discussed.

7.1 A questionnaire by any other natural disaster

Because no previous studies had analysed the effects of a major earthquake event or sequence on farming organisations, very little was documented regarding the potential direct or indirect effects to exposed farms, nor was it known how any impact to the farming organisational community would have to the rural non-farming organisations and *vice versa*. Previous studies had analysed the effects of high-frequency meteorological events on organisations [11, 18, 311], but no empirical evidence for earthquakes specifically had been documented in the literature, and therefore disaster-impact data collection methodologies had to be adapted. In previous organisational disaster research studies, questionnaires were either purposed for a single event [109, 294], or when a single questionnaire was used in two different disaster settings, the organisations sampled were located in urbanized areas like Santa Cruz, California and South Dade, Florida [6].

Therefore to collect these impact data, several technical challenges had to be solved. The first was the development of a survey methodology that could capture a wide-spectrum of disaster-impact and recovery data in a manner that would be applicable to farming, rural non-farming, and urban organisations in post-disaster environments. This was complicated by the breadth of rural industry sectors and the variance in the number of staff employed by rural organisations. As illustrated in Chapters 2, 3, and 6, in all sample populations existed an extreme right-skew of the sampled populations' number of employees per organisations distribution. The Hurunui case study and subsequent survey deployment (Chapter 2) also identified that for some resilience items, the content, diction and syntax of certain questionnaire items that had proven to work for urban organisations in Auckland [78] were found to be inapplicable for small, single employee farming organisations. Additionally, the Hurunui questionnaire illustrated the propensity of sampled organisations, and farming organisations in particular, to omit resilience items due to survey fatigue. This prompted the development of a short-form version of the resilience items (as shown in Appendix B), which dramatically decreased the frequency of resilience item omissions without a significant loss in the Lee et al. [78] model fidelity.

It was also necessary to be able to deploy to differing sample frames rapidly following the event, and without inducing high-levels of survey fatigue for respondents. As the sample response rate from the Hurunui deployment (Chapter 2 shows, a mailed-only deployment methodology was highly inefficient, although being considered an appropriate method given the lack of personal computers and internet service in the area; the mailed-only deployment yielding only 4% after the first contact and 8% after the reminder notice. Introducing the tailored design method described by Dillman [192] showed a marked improvement in the response rate during the Canterbury deployment (Chapter 3, and Appendix A), however it was discovered that is was not possible to locate telephone contact details for all farming organisations. Consequently during the Snowstorm deployment (Chapter 6), it was found that gathering telephone contact details prior to deployment was the most efficient deployment methodology. The timing of deployment was also an important factor in achieving high response rates. In the “follow-up” deployment in Southland, it is likely that the timing of the deployment decreased the response rate as farmers were asked to respond during a particularly busy time of year. As a result, the response from the farming sample was much lower than the non-farming sample, which was relatively consistent with the Canterbury “follow-up” response rate that took place earlier in the year.

7.1.1 The quantitative/qualitative balance

In the questionnaire designs, a major focus was to employ both quantitative and qualitative measures of disaster impact and organisational recovery as a means to document a holistic and multi-faceted representation of organisations’ experiences.

The majority of the quantitative items used were adaptations of items used in previous disaster-impact studies. The two most notable quantitative item examples of these adaptations were derived from Chang and Falit-Baiamonte [111], and Schmidt et al. [113]. As detailed in the methods section of Chapter 3, organisations were asked to rank the disruptive influences of a given list of factors. This method also proved effective in the adapted form, which asked respondents to rank the helpfulness of given factors in mitigating the effects of the event. The results from these two items largely aligned with open-response items (as discussed in Chapters 3 and 4) and provided the data needed to immediately assess the disruptive impact of an event on organisations, as discussed in Chapter 3 with the Organisational Impact Index (the OII Equation 3.1). As shown in Chapter 5, the adaptations from Schmidt et al. [113] provided the method for assessing the organisational repair costs following the event and the functional downtime, which ultimately was used in modelling the likely total asset repair costs from an event, as discussed in Chapter 5 with the Total Asset Repair Cost model (the TARC Equation 5.2).

While there were several positive outcomes with regards to the quantitative items, the results offered a limited appraisal of the overall impacts of the events. The quantitative items used in the questionnaires were less effective in capturing psychosocial impacts of the event, and the nuances of the disruptions and mitigating factors. For example, the quantitative methods failed to capture the disruptive, and psychosocially traumatic experience of staff members having to listen to customers recalling the event throughout the day. Furthermore, due to structure, the quantitative items were less effective at capturing unanticipated or emergent themes, such as the increase on stress levels over the course of the aftershock sequence. Inspired by the work of Smith et al. [11], the use of open-ended items and semi-structured interviews proved invaluable in gathering these types of data. Examples of which can be found in Chapter 4, the results of which were derived from the use of a name-generator to collect informal network support structure data.

The use of qualitative survey items proved efficient in providing a contextualized or nuanced insight into the quantitative results. Although relatively time-intensive, the results showed low omission rates for qualitative items (among the lowest of all items) and relatively detailed responses. That said, there were wide ranges in data quality collected by the qualitative items, which made statistical analyses more challenging.

Ultimately, the use of both qualitative and quantitative survey items proved to be a very important feature of the survey design as the results from quantitative items tended to focus on more quantifiable impacts, such as repair costs of structures. In contrast, qualitative items were useful in identifying impacts that were not explicitly covered by the quantitative items, and were more likely to collect data regarding the psychosocial well-being of the respondent. Including the option of 'other' in quantitative item sets was far less effective in collecting unforeseen categorical options than was the inclusion of an open-ended qualitative survey item.

7.2 Comparing the impacts of the Darfield earthquake and the Southland snowstorm for rural organisations

In comparing the effects of the Canterbury earthquake sequence to the 2010 Southland snowstorm, it is evident that the two events affected both farming and rural non-farming organisations in fundamentally distinct ways. From the results of the 2010 Southland snowstorm (Chapter 6), farming organisations were significantly more affected by the event than rural non-farming organisations. For livestock farming in particular, the substantial livestock losses were the most disruptive factor experienced, and these losses directly translated into decreased organisational performance in the short-term, with several farmers considering exiting (shutting down) as a result of the snowstorm's impacts. These results were largely in-line with previous studies of similar conditions [309, 320].

However during the Canterbury earthquake sequence (Chapters 3, 4, and 5), broadly speaking farming organisations were less affected overall than rural non-farming organisations. While some farming organisations – mostly dairy farms – did suffer from primary mode of production decreases because of infrastructure failures or lifeline disruptions, this circumstance was largely applicable for most of the rural non-farming sectors. Even in the case where the organisation did not suffer major structural damage, the organisation often suffered significant amounts of non-structural damage which needed to be cleaned up, or the building needed to be inspected prior to re-opening. When closed, these organisations were largely unable to operate, and which is why rural non-farming organisations (as well as urban organisations [Appendix A]), cited cash flow as one of their greatest concerns.

The repair costs of rural non-farming organisations were also much higher for non-farming organisations when compared to farms with similar numbers of employees. The differences in costs were due to higher structural damage costs – despite farming organisations incurring a much higher rate of irreparable structural damage to their building stock than non-farming organisations – and significantly higher non-structural repair costs. Even when farming organisations did suffer catastrophic structural damage, the overwhelming majority had very high levels of insurance and some opted to not restore those buildings, which illustrates that some of those buildings used on-farm are not necessarily required for production purposes. Furthermore, the fact that a portion of farms chose not to restore lost stock should be accounted for in modelling scenarios that use probabilistic assessments of stock loss to approximate likely impact costs following an event.

The 18 September snowstorm in Southland and the Darfield earthquake also illustrate the time-sensitive nature of on-farm impacts. The adverse weather created cold conditions that led to widespread lambing fatalities and considerably delayed the growing season, both of which have the potential to seriously compromise farm incomes. When the Darfield earthquake occurred, there were widely reported incidences of irrigator damage and increased well water turbidity which had the potential to damage well pumps and could have proved very disruptive had farms been irrigating at the time. However, because regional farms were not irrigating, well pumps were not destroyed and the base of production for farms was not adversely affected.

A feature that was evident in the Southland snowstorm was the strong economic linkages that exist between the farming and rural non-farming organisations. Most notably for secondary producers like dairy processing or freezing works, experienced a sharp drop-off in available supply in the short- and medium-term respectively. These linkages were not only apparent in downstream effects, but also in decreased spending in suppliers and local service industries as well. These effects were largely relegated to decreased spending on non-essential supplies and services.

The most ubiquitous feature from both events were the psychosocial challenges. Both farming and rural non-farming organisations cited the effects of stress to be one of the biggest challenges faced in the aftermath of the event. The causes of these feelings of stress were related to a wide variety of issues, ranging from stock loss, extreme workloads, staff listening to customers discuss their challenges and sleepless nights caused by the several thousand aftershocks. These results support the need for future psychological studies on rural organisations post-event that closely analyse the effects of stress, its evolution or persistence over time, and effective support strategies. This is especially needed given the likely increase in agricultural disasters as a result of climate change.

7.2.1 How both disasters evolved over time

The nature of the events dictated that both evolved in different manners, with some shared commonalities. The direct effects of the Canterbury earthquake sequence lasted for several years, with on-going aftershocks across the central Canterbury plains and several that caused massive damage and loss of life in the regional city of Christchurch. For the rural areas, the more common direct effects of these repeated aftershocks were interrupted lifeline services and the stress brought on through the exposure of the thousands of aftershocks in the Canterbury Plains; the locations of these aftershocks can be found in Figure 4.1. When organisations in Canterbury were contacted in June 2012, approximately 1.5 years after the Darfield earthquake, the most commonly cited 'greatest challenge' reported by both farming and rural non-farming organisations was stress by a significant margin. Many of these farmers originally had stated that there was no serious challenge brought on by the earthquake, illustrating that despite not necessarily incurring any major structural or non-structural damage, the persistent exposure to the hazard significantly increased stress levels.

In contrast, the direct effects of the snowstorm event only lasted for approximately 10 days, which is relatively protracted when compared to previous snowstorms in Southland that more typically last approximately 48 hours. Once the temperatures returned to more seasonal conditions, stock mortality rates were no longer the concern, and farmers looked towards methods of mitigating the financial impact of the event.

The evolution of stress following the snowstorm took a markedly different recovery trajectory. Immediately following the event, there were extremely high levels of stress due to the livestock loss, extreme workload and concerns regarding the viability of the farm. Once the dead stock were removed, the stress brought on by the extreme workloads and stock losses largely dissipated, however the financial concerns remained and became more poignant during tailing (approximately one month later), when exact losses were calculated. However when commodity prices increased so dramatically in the following months, the financial stress was alleviated for most of the sample.

In both the earthquake and snowstorm events, the production base for farming organisations was not seriously compromised and as a result, lacked the distinctive characteristics of a drought-like stress event, or a perturbation like a tsunami inundation which requires several years to return to pre-event soil productivity levels.

For rural non-farming organisations, the snowstorm and earthquake events had very distinct impact signatures. During the earthquake event, rural non-farming organisations suffered heavily from structural and non-structural damages which forced them to cease operations for clean-up and repair purposes. That said, there were several examples of increased business due to Christchurch residents coming out to view the damage, which yielded benefits for those organisations able to reopen quickly. The increased customer base appeared to be related to the recovery phase, with construction workers requiring services or Christchurch residents escaping from the urban damage during subsequent aftershocks. The rural non-farming organisations affected by the Canterbury earthquake sequence did not widely report decreases in their local customer base for any extended period of time. In contrast, for rural non-farming organisations affected by the Southland snowstorm, customer activity dropped for an extended period of time following the event. In the short-term immediately following the event, the majority of organisations closed for only a period of a few days. However, upon reopening, several non-farming organisations noted decreases in customer spending or customer activity. These decreases were noted by both farm support organisations and general service organisations, and were related to the cash and time-strapped farming organisations. The duration of the changes in customer behaviour were related to the types of services being provided. For example, farm-support organisations that provide seasonal goods and services (goods that are typically bought once a year) experienced a more pronounced drop in customer activity as farming organisations were in stronger financial positions later into the spring and summer months after the yearly discretionary purchases were made. For the industries that provide regular goods and services, customer activity returned to pre-event levels as the commodity prices strengthened.

7.2.2 The mitigating strategies that were helpful

The mitigating strategies employed by affected rural organisations following both events showed several similarities. For farming organisations, the most commonly used mitigating strategies was the reliance on informal networks, most notably their neighbours. Immediately following the event, farmers in Southland and Canterbury utilised their neighbours for labour support, either by assisting one another in picking up dead stock, helping repair damaged structures, sharing resources such as stock covers or allowing access to dairy sheds. The support from informal networks were adaptive and emergent, with no instances of pre-existing agreements between neighbours found.

For farming organisations in Canterbury, informal networks were also used for psychosocial support purposes in the short- and medium-term. Taking the form of simple fence-line chats, or telephone calls, the act of discussing the event or getting together socially was found to be tremendously helpful in decreasing stress. This behaviour was also found to be present in the rural non-farming organisations in the medium-term.

The use of informal relationships amongst farming organisations extended into two types of assistance: labour and psychosocial assistance. Immediately following the event, these relationships were used to source both types of assistance. As time passed, the use of labour assistance dropped and informal relationships were leveraged primarily for psychosocial assistance. The use of these relationships illustrates the importance of social capital which played an integral role in affected organisations' ability to adapt to the adverse conditions.

Other studies have identified the importance of social capital in rural areas, noting its usefulness extends to the psychosocial state of the farmer [286], the farming organisations [11, 14], and the wider affected rural community [282]. The results presented in this thesis expand on this notion of social capital being used for the purposes of organisational assistance, noting the two types of assistance generally provided following an earthquake event and the evolution in the type of assistance provided.

Rural non-farming organisations relied heavily on their professional networks to recover, which included suppliers or lenders. While these were more formalized channels of assistance, they were built upon the pre-existing relationships that had been developed and in many rural cases, these professional and personal networks are highly related and the distinction between the two networks can be muddled.

Rural Support Trusts also played an important role in helping mitigate the effects of the events for farming organisations. In both Canterbury and Southland, the distribution of packages and checking in on affected farms proved to be very helpful, mostly because it decreased the effects of isolation brought on by extreme work loads, and let the farmer and their family know others were thinking about them. One point of note is that when farms were not contacted, the feeling of isolation increased. The collaboration between industry groups, such as Federated Farmers, and other related industries also proved beneficial for the recovery phase, as volunteers from these groups assisted the initiatives of the Rural Support Trust (RST) or helped organise post-event information meetings.

7.2.3 Impacts on organisational performance

In terms of organisational performance, the snowstorm event seriously compromised the viability of affected farms through the destruction of uninsured livestock which created the potential for 20%+ losses in yearly revenue. Without the increase in the commodities market, several farmers sampled would have considered exiting the industry. Rural non-farming organisations, while being far less affected, did experience decreases in customer numbers and average spending during the months prior to the commodity price increase. For the service industries, customer numbers rebounded immediately following the event while for farm suppliers, discretionary spending that has some degree of seasonality had a more pronounced affect on total sales and would not recover until the year following.

In contrast, organisations affected by the Canterbury earthquake sequence largely experienced no general negative impacts to organisational performance. For farming organisations, this was because the mode of production was largely unaffected. Even in the case of dairy farmers who despite suffering from drops in production, did not experience decreased organisational performance or revenue decreases because the national dairy co-ops paid for lost production. As illustrated by the TARC model (Equation 5.2), despite incurring significant repair costs, the Canterbury earthquake sequence had no measurable effect on organisational performance.

As mentioned previously, in the case of rural non-farming organisations, organisations did suffer from decreases in revenue immediately following the event, but often quickly recovered these losses through increased customer numbers, either because regional residents wanted to view the damaged area, escape the damage in Christchurch, or because of the construction crews requiring additional services. Although in the short-term, there were negative effects, in the medium term the event has stimulated some increased activity and development.

The non-farming organisations in Southland experienced a more pronounced impact on organisational performance, depending on the industry sector. For the secondary producers – organisations that process primary industry goods – the lack of available livestock proved to have an impact on production levels and consequently affected revenue. For the farm-support organisations that provide goods seasonally or semi-regularly, there was a notable loss farm purchasing power during the spring-time when farms require a certain set of goods and services, causing drops in revenue for the year. For the non-farming organisations that provide regular services, the drops in revenue only existed until the rise in commodity prices took effect, unto which time customer levels returned to pre-event states.

7.2.4 Factors relevant for farming organisations

For farming organisations, certain factors, such as the nature and timing of the event, the farmer's informal network, and the relief support available appear to control the event's impacts on farming operations. Three general conclusions from this research are listed below.

1. These factors were found to influence the level of natural disaster impacts to farming organisations:

   Impact to production base: In the Canterbury earthquake sequence, the lack of impact to the base of production proved to mitigate the overall impact of the event. In contrast, the high livestock losses observed following the Southland snowstorm were a significant shock to the production system and sufficiently disruptive for some affected farms to consider exiting the industry;

   Critical services disruptions: The critical service or lifeline interruptions were the most disruptive impact of the earthquake event, with modern farming systems becoming increasingly dependant on distributed critical services. These dependencies extend beyond simply production requirements (e.g. electricity for milking sheds), and extend also into personal and family needs as well (e.g. telecommunications, entertainment, social connectivity);

   Seasonal vulnerability: At certain times of the year, farming organisations have periods of increased sensitivity to impacts such as lambing or summer months where irrigation may be necessary;

   Ability to access needed resources quickly: Farming organisations required resources such as supplemental feed, medication, and human capital. That said, it should be noted that the right type of assistance was very important, and raw manual labour in the form of volunteers was not always helpful. Farmers often noted that training and managing volunteers was counter productive to their recovery effort which took both a financial and emotional investment during a period of heightened sensitivity (e.g. post-disaster recovery environment);

Pre-existing organisational conditions: Cash flow and debt levels have long been predictors of organisational survival post event, and in both the earthquake and snowstorm events, pre-existing organisational conditions were considered very helpful in mitigating the effects of the hazard; and

Commodity prices: The Southland snowstorm illustrated the effect of commodity prices on organisational viability. Prior to the rise in prices, several organisations were noted as stating they may exit as a result of the event. However, after the prices rose, and much of the revenue losses were recouped, the likelihood of exiting decreased substantially.

2. The mitigation strategies found useful were:

Informal network relationships: Informal network relationships were heavily utilised both in the short and medium term. Informal relationships, i.e. social capital, were used for both labour and psychosocial support purposes in the short-term. Only psychosocial support was utilised in the medium term

Disaster assistance: External assistance took the form of labour, psychosocial, and information support, and included volunteer labour, industry support groups, governmental groups such as MPI and RST, and post-disaster meetings

Insurance: Insurance was helpful in the case of damage to assets and therefore was useful in the case of the earthquake. Following the Southland snowstorm, livestock insurance packages were proposed by a regional insurer. However, the packages saw limited uptake due to the perception of it being too expensive based on the likelihood or risk of another event. The view of livestock insurance as an unjustifiable expense for the snowstorm – perceived to be a relatively low-frequency event – while perhaps justified, highlights the idea that alternative options such as building covered yards may be more efficient.

3. Farming organisations rely on their adaptive capacity to manage the effects of a disaster and lack formal disaster response and recovery plans. Farmers used their informal network contacts in a manner similar to the pre-existing arrangements outlined in formalized disaster response and recovery plans. However, one negative aspect of the adoption of an adaptive response is that farmers often subjected themselves to extreme workloads following events, which ultimately threaten their

own health and safety, and is unsustainable for extended periods of time. It also negatively affects their psychosocial state, with extended periods of isolation, feelings of futility, and helplessness.

7.2.5 Factors relevant for rural non-farming organisations

For rural non-farming organisations, generalizations are made more difficult by the wide breadth of industry sectors and organisation sizes present in the sample group. However, some generalized conclusions are listed below:

1. These factors can affect the level of natural disaster impacts to the sampled rural non-farming organisations:

   The ability to remain operational/producing: Maintaining cash flow was the primary concern for the majority of rural non-farming organisations post-event and as a result, remaining open or reopening quickly was the most critical factor. In the case of the earthquake, organisations that were capable of reopening quickly also noted the initial increase in their customer base due to Christchurch residents coming to view the damage. In the case of the snowstorm, the ability to reopen quickly was less important as many customers were incapable of reaching businesses. One of the most major contributors to business interruption durations was the effort required in repairing or cleaning up non-structural damages.

   Critical service disruption: Organisations found critical service or lifeline interruptions to be highly disruptive. This was most notable in the case of the Canterbury earthquake sequence, where critical service disruptions were far more prevalent when compared to the Southland snowstorm.

   Ability to access needed resources quickly: Organisations that were able to resupply, repair, or relocate quickly were able to return to pre-event operations or develop alternative operations more rapidly. Sourcing replacement stock was most notable in the case of the Canterbury earthquake sequence, which caused stock losses either from ground shaking or spoilage from extended periods of closure and disrupted critical services.

Pre-existing organisational conditions: Metrics such as cash flow and debt levels, as stated earlier, are often noted as being important to organisational survival post-disaster, and the availability of readily available resources – which are often a bi-product of organisational health, have significant benefits.

Degree to which farming organisations were affected: Decreases in farming organisational performance have shown to negatively impact non-farming organisational performance. This was most widely observed in the Southland snowstorm event, where affected farming organisations cut back on non-essential expenditures, and the secondary producers experienced major decreases in production due to the lack in supply.

2. Mitigation strategies found useful were:

Professional and informal network relationships: Immediately following the event, professional network relationships were most heavily leveraged to accomplish tasks such as sourcing replacement stock. However, over time, informal network relationships were more commonly used as a means of psychosocial support.

Insurance: Insurance was leveraged to recoup several losses, which proved helpful in the medium and long-term, but not immediately following the event. Notably, due to the recurring earthquakes, organisations would often incur minor losses that were either below or marginally above their excess, but chose not to claim due to the resulting rise in premium rates.

7.3 Policy recommendations to increase rural organisational resilience to natural hazards

From the conclusions of this thesis, policy recommendations designed to increase farming and rural non-farming organisational resilience to natural hazards are listed below:

1. Foster communication, research and development efforts between Civil Defense, the Rural Support Trusts, the Ministry of Primary Industries, and Riskscape that improve impact and cost information gathering efforts following natural hazards, and provide data ingest pathways accessible to decision makers.

- **Design:** create standardized impact assessment survey methodologies employing the Organisational Impact Index (Equation 3.1) in disaster-response situations to assess the short-term disruptions experienced by both farming and rural non-farming organisations. In the case of earthquakes, areas that experienced the highest intensity shaking should be prioritized. Also use open-response items to capture emergent themes not identified by the OII such as psychosocial stress levels, as described in Chapters 3 and 4. In the case of future earthquake events, utilize the TARC model (Equation 5.2) to assess greatest levels of repair costs. All data resulting from these survey efforts should be immediately digitized and stored in a cloud-based repository, accessible to the different agencies, and analysed in real-time to feed information back to the RST and CD to inform the response effort.
- **Implementation:** Utilize Civil Defence expertise for disaster management and data collection purposes. The incorporation of the OII and TARC impact modelling techniques discussed previously can be performed by analysts within RiskScape or MPI after the data has been uploaded into the cloud environment. After processing, the RST can leverage their networks and associated agents who have local experience with the affected population to reach out to the highest priority areas and report results. Databases on farm area and staff should be maintained for rapid analysis post-event; these databases would also be useful for modelling purposes and simulations during peacetime. Additionally, closed-response items could be refined to capture some of the psychosocial impacts identified in this thesis, however open-ended responses should always be present in these data capture devices.
- **Rationale:** A standardized impact assessment tool would provide a significant contribution to the identification of the needs of affected organisations immediately following the disaster and during the months following as well as increase the timely and effective use of resources; it can also decrease the psychosocial trauma caused by the extreme workloads and isolation of the event, and improve hazard impact assessment models. The infrastructure required is already in place with the Rural Support Trusts, who have local knowledge, and the capacity to use agents from private firms who have a pre-existing relationship with the affected, and the Civil Defence offices that have expertise

in managing natural disasters. By fostering information sharing across the multiple agencies, it is possible to leverage the local skill set of the RST and CD to gather data, the data resources of MPI, and the analytical capacity of RiskScape to deploy these standardized tools quickly, ingest good data rapidly, distribute those data to analysts for processing, and provide clear results to decision makers in real-time.

2. Involve rural communities in recommending activities that build social capital before and after disasters. An example of an activity would be to increase the frequency of rural community meetings – both in peacetime and following natural hazard events – encouraging increased communication between farming and rural non-farming organisations to attend as a means to build social capital through community cohesion and networking. These meeting could also serve to build relationships between rural and scientific organisations.

    - **Design:** Reach out to rural communities through the RST to develop events designed to build social capital. As developing these events will take time, begin by increasing the frequency of meetings prior to and following events, explaining the nature of phenomenon utilizing scientific experts, including basic management information applicable for both farming and rural non-farming organisations, and providing a social function following the event.
    - **Implementation:** Initiate phone surveys to determine level of interest in different types of social events. Identify the most popular ideas, and initiate them as rapidly as possible. To initiate social events rapidly or post-event, replicate methods used following the snowstorm or earthquake events, utilizing the cooperation of GNS or university scientists, Federated Farmers and the Rural Support Trusts for data collection, investigation, and analysis purposes. The research organisations can facilitate the analysis of data collected by the Rural Support Trusts, who often are understaffed and overworked in post-disaster environments. Also, include non-farming industry groups and place effort to ensure information dissemination is applicable to the non-farming sectors.
    - **Rationale:** increasing community integration and engagement has demonstrable improvements in community resilience following a disaster, and by providing a forum for rural community members to form additional social

bonds, the connectivity of the community will increase. Connections formed at these meetings may prove helpful in expanding individuals social network, which is often used to mitigate the effects of various types of natural disasters. Specifically for farming organisations sampled in this thesis, rural community meetings were identified as helpful by the respondents because the nature of the event is explained, practicable impact management techniques are offered, and the best-practice options going forward are explained.

3. Promote the development of disaster response and recovery planning strategies for farming organisations through a collaborative, bottom-up approach of involving farmers in developing actionable response and recovery strategies, with specific focus given to critical supply disruption and resource shortage preparedness.

    - **Design:** to improve rural organisational disaster resilience through the use of formalized planning strategies. Planning strategy guidelines should be promoted by the RST and CD, but the strategies themselves should be developed from the farmers themselves to improve buy-in.
    - **Implementation:** increase the promotion best-practice planning strategies for disaster preparedness and response during peacetime through Rural Support Trust networks and community meetings. Guidelines should promote farmers' natural tendency to preference adaptive capacity, potentially by encouraging increased communication between within the farming community as well as between farmers and rural non-farming organisation. Additionally, strategies such as maintaining back-up lifelines on site, diversifying the supply chain and maintaining a list of back-up supplies are potential areas to be encouraged. The development of financial incentives (potentially through the use of tax-breaks) for the development of formalized strategies should be reviewed. The costs may be justified as increasing farming organisational resilience will ultimately decrease the need for MPI to declare medium or large scale adverse events because risk management options will be more readily available.
    - **Rationale:** while some organisations were able to responsively access resources for their organisation without formal disaster plans, formalized planning strategies develops systematic, robust processes that prioritize the actions for the organisation which maximizes their efficiency during times of

crisis by structuring the response and recovery phases to minimize the impacts to the organisation, and does not entirely rely on adaptive strategies such as the use of informal networks to be effective. Additionally, formalized planning strategies identify weak linkages within the organisation's operations and can prompt the improvement of weaknesses during peacetime. Importantly to note, formalized preparedness plans must be done rigorously, and must be practised to be effective. If done inadequately, the plans can create a false sense of security. There is also the challenge of convincing the smaller rural organisations that these formalized plans are of value as many SMEs do not find these plans necessary at the smaller scales.

7.4 Future work

From these results, it is clear that rural organisations illustrate unique impact characteristics when compared to rural non-farming or urban organisations, and consequently further research regarding the effects of earthquakes on rural businesses should be conducted. Further work is required to better characterize and constrain the nature of the psychosocial impacts of the Canterbury earthquake sequence, and determine if any lasting effects may exist. Future studies should continue to test the applicability of resilience quantification methodologies in different developed, high-intensity contexts. Also, studies should follow up with organisations in the Canterbury Plains to identify what lessons have been learned by experiencing the earthquake sequence and how they have adapted over time. Additional deployments of the OII (Equation 3.1) should be conducted to determine if the disruption assessment is applicable following different types of natural disasters. Furthermore, the TARC (Equation 5.2) models should also be deployed in future earthquake events in New Zealand and other OECD countries to test the applicability of the model under different conditions and contexts. Comparisons between the OII and TARC models with HAZUS methods for the agricultural sectors in the United States would also be of interest. Finally, further work is needed to determine how farms in New Zealand can hedge their exposure to fluctuations in the commodities market in the case of sudden decreases occurring following a natural disaster, a contingency that could cause above-average exits regionally and could threaten the viability of rural non-farming organisations.

Appendix A

Organisational resilience and recovery from the 4 September 2010 Darfield (Canterbury) earthquake: preliminary impact and organisational performance analysis

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A.1 Overview

Collecting and analysing the impacts of the Darfield earthquake across a wide variety of sectors provided the opportunity to contrast against the impacts and recovery strategies of the farming and rural non-farming organisations. In this chapter, the impacts of farming and rural non-farming organisational sectors and directly compared to those of urban industry sectors and organisations located within the central business district (CBD).

A.2 Contributions

Mr. Whitman worked in collaboration with Mrs. Stevenson and Ms. Kachali to develop the questionnaire used for data collection. Mr. Whitman deployed and collected data for all rural organisations while Mrs. Stevenson and Ms. Kachali collected data for all urban organisations. Dr. Seville, Dr. Vargo, and Dr. Wilson all advised on the questionnaire development and deployment methodologies, and all authors provided in-depth reviews of the manuscript.

A.3 Abstract

This appendix chapter presents the preliminary findings of a study which assesses the resilience and recovery of organisations following the 4 September 2010 Darfield (M_w 7.1) earthquake in the South Island of New Zealand. Sampling included organisations proximal and distal to the fault trace, organisations located within central business districts, and from seven diverse sectors. Organisations most likely to close for a period of time as a result of the earthquake were within central business districts, and hospitality sector. Organisations that had perishable stock and livestock were more heavily reliant on lifeline services and therefore more dependent on rapid restoration of service. Staff well-being, cash flow and customer loss were major concerns for organisations across all sectors. Most organisations found the most helpful factors in mitigating the effects of the earthquake were their relationship with staff, the design and type of buildings, and lifeline service continuity or rapid restoration of services.

A.4 Introduction

The 4 September 2010 Darfield earthquake created significant operational challenges for organisations in the Canterbury region of New Zealand. Organisations faced disruption of critical infrastructure services, building damage, impacts to staff welfare and restricted access in many areas which led to immediate significant impacts and affected recovery efforts in the months following. The economic impact of the earthquake to organisations in the region was of major concern, especially when considered in the broader context of New Zealand's economy which was still recovering from the global financial crisis.Accurate information regarding the level of impact and disruption sustained by organisations following the earthquake was and continues to be highly sought after by civil defence and emergency managers, government officials, the business community,researchers, and other stakeholders as it is necessary to make informed decisions about recovery.

The New Zealand Treasury's preliminary loss estimate of the Darfield earthquake was $5 billion NZD in total and approximately $0.75 billion NZD of this cost was attributable to commercial loss [204]. However,these estimates were primarily based on the generalised assumption that predominantly organisations in damaged areas would be negatively affected, not taking into account a variety of other factors such as spatial or sectoral variability and relationships, changes in organisations customer bases, or supply chain challenges. In previous circumstances, loss estimates that are based on physical damages alone only represent a small portion of the potential costs to an organisation [111, 262]. The recovery of an organisation needs to be considered within the context of a dynamic spatial framework that also acknowledges interdependencies and downstream effects.

While many studies have focused on the resilience and recovery of households after natural disasters, very few have analysed the impact earthquakes have on organisations [109, 111, 117, 217]. Studies of organisational recovery (more commonly framed as business recovery) identify factors that may influence the level of impact sustained by organisations as a result of a disaster; however further research is required to provide a better understanding of these potential relationships. Organisations are part of local communities and essential community functions on a day-to-day basis. Importantly, organisations are also critical during the response and recovery periods following a disaster [353]. Consequently, it is critical for organisations to be resilient in order to ensure organisational survival and to minimise the disruption caused by disaster to societal routines.

By cataloguing the organisational impacts following natural hazards, organisations may better prepare for and mitigate these risks, thus decreasing the overall effect of the event. Generalized impact summaries can obscure many spatial and sector-level effects due to the variety of organisational types and structures. Analysing the effects earthquakes have on organisations from a spatial and sectoral perspective is a necessary step in improving practicable mitigation techniques that will improve loss estimates, better inform policy decisions, and increase overall organisational and community resilience.

In this appendix chapter we present the results of a survey of 376 Canterbury organisations following the Darfield earthquake. This study assesses the physical, spatial and network effects of the earthquake and subsequent aftershocks on a range of industry sectors and locations throughout Canterbury. The sectors sampled for the study include: Information and Communication Technology (ICT), Critical Infrastructure Organisations (Lifelines), Fast Moving Consumer Goods (FMCG), Hospitality, Trucking, Building Suppliers and Agriculture. The location samples included the Christchurch CBD, the Kaiapoi CBD, and the rural areas proximal to the epicentre which was comprised of farming and rural non-farming organisations primarily. The direct and indirect impacts of the earthquake are contrasted against organisational and network challenges post-disaster to identify the most disruptive factors. Organisations were sampled between November 2010 and early February 2011. Data regarding the immediate organisational challenges brought about by the earthquake help to identify the importance of geographic and network effects and also predicate the importance of the structural integrity of the built environment.

In the months following sampling, Canterbury has been further impacted by highly damaging aftershocks in 2011 on 22 February (M_w 6.3), 13 June (M_w 5.8 and 6.4), and 23 December (M_w 5.8 and 6.0).The February event caused the most significant damage to the physical, built and social environments of the city. However all three events caused significant disruptions. The research on the impacts of the Darfield earthquake has proven valuable for informing recovery efforts following these later events. This is one of the few studies that gathered information on the organisational impacts of the Darfield earthquake without the confounding effects of subsequent significant aftershocks. It is a useful record of the challenges organisations were contending with when struck by the 22 February event.

A.5 Settings and hazards

The M_w 7.1 Darfield earthquake along the Greendale Fault produced an East-West trending, 28km long surface rupture through low relief farmland 40 km west of Christchurch [198, 199]. The Greendale Fault was unknown prior to the event and is among several other E-W trending strike-slip dominated faults that are located in the Canterbury Plains. Similar faults in the area, such as the Porter's Pass Fault, accommodate a portion of the transpressional plate boundary motion between the Australasian and Pacific plates and have the potential to generate similar earthquakes.These faults present a significant and poorly understood hazard that requires further research [354].

While the fault rupture occurred within a relatively compacted system (the Burnham formation (c. 18,000a) gravels capped by Lismore series soils (Brown soils)), much of Christchurch is built upon soft, uncompacted (Kaiapoi or Tai Tapu) soils (Recent and Recent Gley Soils respectively) which act to amplify the effects of ground shaking and are susceptible to liquefaction. Earthquake intensities,derived from Felt Reports, as high as Modified Mercalli Intensity (MMI) 8 were reported in Darfield, Hornby (10km west of Christchurch), and Lyttleton (11km southeast of Christchurch). Intensities in the Christchurch CBD following the earthquake ranged from MM3 to MM8, with a peak ground acceleration (PGA) value of approximately 0.25g [355]. While the highest PGA value of 1.26g was recorded 5 km from the epicentre, earthquake intensities proximal to the epicentre showed similar levels to those recorded in the Christchurch central business district (CBD), Darfield and Kaiapoi [355]. Medial and distal organisations primarily experienced effects related to strong ground motion and liquefaction. Organisations proximal to the fault trace were impacted by not only strong ground motion and liquefaction, but also damage to roads which suffered several meters of lateral offset, changes to the water table and, along the surface expression, 1 meter or greater of vertical offset [199].

The majority of damages to structures reported in Christchurch and areas proximal to the epicentre were consistent with an MM8 level event, and the earthquake produced ground motions that approached or exceeded Christchurch city building design levels [202, 356]. Unreinforced masonry (URM) buildings in Christchurch were most affected by strong ground motion. In total, 21 percent of URM buildings in Christchurch were red-tagged (deemed unsafe to enter), the majority of which were located on arterial city lines or within the CBD [202]. Many of these buildings were two stories, situated in a row, and leased to organisations [202].

Liquefaction presented the most widespread hazard to the city of Christchurch and surrounding communities. Prior to this earthquake, Canterbury's regional council Environment Canterbury (ECAN) estimated approximately 50 percent of Christchurch's urbanised area to have a high liquefaction potential [357]. During this event, liquefaction caused sand boils, lateral spreading, differential settling, and ground deformation that damaged the roading network, critical infrastructure, building structures, and farmland [129, 358]. There was significant liquefaction in the township of Kaiapoi and eastern suburbs, which created large amounts of lateral spreading causing structural damage to the CBD and built infrastructure [359]. Approximately 60 km of the road network in the Christchurch area was significantly damaged [201]. Liquefaction was also very disruptive for buried utilities such as water mains, sewerage, communication and power cables [201].

Christchurch's main power distributor reported more than 166,000 customers were without power at some point on 4 September, but by the end of the day that figure had dropped to just over 15,000 [201]. The sharp restoration curve was in part due to the fact that the damage to the electrical network was limited to conductors within the transmission and distribution lines. Several telecommunication cell sites lost power due to electricity disruptions outlasting backup battery power, requiring diesel generators for continued operation. Restoration of water and wastewater services was slower. Approximately 10 percent of Christchurch city and 50 percent of Kaiapoi were without wastewater for several days following the earthquake. Similarly, 15 to 20 percent of Christchurch was without water immediately following the earthquake, but by the end of the week less than 5 percent were still without water [201].

A.5.1 Organisational experiences post-disaster

Within the domain of organisational disaster studies, there are relatively few impact assessments that have analysed the effects of earthquakes on organisations [6, 7, 110, 111, 175, 273, 360]. Organisational impacts fall into several broad categories including direct physical damage to organisational property, indirect damages or losses caused by operational problems, critical service interruptions, closure (business interruption), staff attrition, and relocation costs [109]. Indirect losses related to disasters emerge throughout the recovery period. For example, Comerio [218] argues that organisational downtime required to plan, finance, and complete repairs, temporary relocation costs, and the need for additional human resources to facilitate recovery work are real and quantifiable cost of earthquakes. Several studies have also documented the major financial impacts of critical service infrastructure (lifeline) disruptions which cause businesses to shut down or operate less efficiently [3, 4, 212, 273].

Studies gauging the impacts of disasters on organisations have also investigated which factors contribute to an organisation's vulnerability to direct and indirect losses. Organisation size has been implicated as an important predictor of organisational vulnerability in a number of studies [8, 110, 173, 215, 216, 224], with smaller organisations experiencing greater failure rates. Small to medium size enterprises (SMEs) tend to have limited capital reserves to draw on following a disaster, and are therefore more reliant on alternative measures to maintain operations if revenue streams are disrupted [6, 110, 225]. Organisation age is also a potential liability following a disaster, as with SMEs, younger organisations often have limited capital reserves [216, 224], fewer assets, as well as smaller networks from which to access resources.

Chang and Falit-Baiamonte [111] and Zhang, Lindell, and Prater [8] suggest that disaster impacts and rates of organisational survival post-event are distributed unevenly across industry sectors. Organisations that employ advanced technology or that are capital intensive (i.e. require large amounts of capital resources to operate) are less likely to fail [361]. Also, a firm's average staff level of educational attainment is positively correlated to survivability [224]. Therefore, sectors that are more capital intensive and require specialized expertise may show higher survivability post-earthquake. Similarly, sectors that rely on discretionary spending or smaller local markets can be more vulnerable to impacts. Kroll et al. [3] found that single location retail, trades such as finance and real estate, and service organisations in the cities of Santa Cruz and Oakland, experienced proportionally greater losses and had more difficulty recovering than other types of organisations.

There is evidence to suggest that certain sectors value approaches to hazard mitigation planning strategies differently. Stephenson et al. [120] found that planning strategies, such as dedicated emergency management staff and the development of emergency management plans among other techniques, were more likely to be found in the health and community sector than other sectors sampled. This may be in part due to the necessity of the health care industry to follow high reliability organisational practices such as emergency management planning [362].

Organisational location has also been implicated in the impacts experienced by organisations. Chang and Falit-Baiamonte [111] found that organisations in central business districts (CBDs) tended to experience more neighbourhood related problems, including diminished parking, transportation disruption during reconstruction, and issues related to the negative perception of the business district. Businesses located in heavily damaged areas, especially if they depended heavily on a local customer-base, suffered more than others [7, 110, 215]. SMEs are especially vulnerable in urban areas as they are more likely to operate from a single location, lease as opposed to rent, and occupy unreinforced masonry (URM) buildings which are vulnerable to earthquake damage, due to the lowered rental costs of older building stock [110, 125]. Larger organisations are more likely to have multiple sites, which act to distribute risk, lowering the potential for a single natural disaster to disrupt all operations.

Organisational attributes that mitigate the effects of disasters and allow organisations to adjust to potentially damaging changes post-disaster can broadly be referred to as an organisation's resilience. These components of organisational resilience incorporate elements of planning and adaptive capacity [120, 363]. This planning and coordination facilitates responsive and adaptive actions during and following a crisis [364]. An organisation's ability to adapt to a changing environment, its adaptive capacity, has been widely accepted in the literature as a critical component to the growth and success of the organisation [365, 366]. Adaptation is also linked to an organisations ability to mitigate disaster impacts [363, 367].

While planning strategies may be developed prior to a disaster, business owners are more likely to prioritise employee life-safety and fail to address business continuity operations such as the development of recovery plans or business relocation preparations [6]. Furthermore, disaster experience does not necessarily increase the development of organisational planning strategies. In the case of the 2003 earthquake in the Fiordland region of New Zealand, less than half of the sampled businesses in Te Anau and Manapouri implemented preventative measures following a M_w 7.2 earthquake [175]. These SMEs were less likely than residents to stockpile emergency consumables and secure furniture or other heavy items, actions that have been identified to reduce damages and lower interruption times for organisations.

Some limited evidence exists in the organisational resilience literature to suggest that certain organisation types are more adaptable post-disaster. Rural organisations and those in the primary sectors show a strong focus on their adaptive capacity, showing high use of social, informal, and family networks to operate following natural disasters [148, 239]. The same is true for rural family-run organisations, who have shown to be highly affected by changes in social capital and show a tight coupling to the health of the local community [137, 138, 241]. Farming organisations, the majority of which include family members, are often exposed to the threat of decreased resilience as the natural hazard negatively affects both their family and organisational systems, both of which may become overwhelmed during crises [241]. Also, the delineation between family and organisational resources are often shared. In the United States, Winter et al. [243] found the practice of bootstrapping, or the transfer of family resources to the organisation, occurred in nearly half of family owned organisations during normal operations. Importantly however, while natural hazards have generally been studied for farming organisations, the effects of earthquakes is largely omitted in the literature and consequently very poorly understood.

A.6 Methods

The results presented in this appendix chapter are the first part of a two year study which will track the on-going recovery of Canterbury organisations in the aftermath of the Darfield earthquake. The first survey was designed to capture initial impacts, disruption, and challenges faced by organisations, as well as information about organisational attributes, relationships and strategies that may have helped mitigate the impacts of the earthquake.

The survey captured mainly quantitative data, and was supplemented by a limited number of qualitative questions to enhance the depth of understanding about organisations experience of the earthquake. In general, the type of data captured was subjective; the responses reflect only the subjective evaluation of those who responded. Fewer items collected objective data, such as changes in revenue and changes in the total number of employees. While subjective data has inherent limits for interpretation, subjective data provides for initial estimates whereas many objective data are not available in the short term following the event. However, objective data will be collected in subsequent data captures and comparisons between the subjective initial estimates and later objective data will be made possible.

Questions were designed to capture the effect of the earthquake on the organisation by isolating the overall change observed following the event. The limitation in this methodology is that the changes identified are relative, and do not establish the state of the organisation prior to the event. The conclusions made from these data therefore do not resolve the variable of the pre-existing condition of the organisation, which is an inherent limitation of sampling organisations post-disaster.

The survey included a shortened form of the complete Benchmark Resilience Tool developed by the Resilient Organisations Research Programme [78, 120, 238], as explained in Appendix B. The complete Benchmark Resilience Tool was comprised of 13 indicators which were formed using several items per indicator while the shortened form of the tool used only 1 item per the 13 indicators. This shortened version of the tool was intended to measure an organisation's resilience thumb-print without significantly adding to the length of the survey. These thumb-print results will be compared to results obtained from the use of the complete Benchmark Resilience Tool in subsequent surveys.

The collection of the survey data was approached using a modified multi-media version of the total design method described by Dillman [368] which consists of an initial mailing followed by a series of mailings and telephone calls. Our modified version, consisted of an initial mailing or a physical drop-off, followed by a telephone call. When reached by telephone the potential respondent was offered response options which included: returning the survey booklet by mail, completing the survey over the telephone, completing the survey via an online survey engine, or completing the survey in softcopy and emailing it back.

Data collection took place between 17 November 2010 and 18 February 2011. Organisations were given five weeks to respond to questionnaires if they preferred not to answer by phone. Respondents could also request a meeting with the researcher to fill out the questionnaire in person. The use of these multiple data collection methods was necessary to accommodate organisations which were, in many cases, too busy to complete the survey over the phone or return it by mail and organisations which had relocated and not received the original paper copy of the survey.

A.6.1 Sample

Organisations were selected using a stratified random sampling technique based on industry sector and geographic location. Industry sectors included those which are a part of the Canterbury Regional Economic Development Strategy (CREDS) such as the Information and Communication Technology (ICT) and agricultural sectors, sectors that provide services critical in response and recovery efforts, and sectors that capture consumer discretionary and non-discretionary spend. The sample largely consists of small to medium sized for-profit organisations; however organisational structure did not serve as a selection criteria.

Organisations were also selected by area. Two sample groups were selected based on their location relative to the fault scarp in the rural Selwyn District, and are herein classified as rural farm and rural non-farm. Organisations were also selected within the Central Business Districts (CBDs) in Christchurch, Canterbury's largest city and economic centre, and Kaiapoi a smaller town 20km north of Christchurch which was heavily impacted by liquefaction and lateral spreading.

The final locations and sectors selected for sampling include:

- Information and communication technology (ICT)
- Critical infrastructure organisations (Lifelines)
- Fast moving consumer goods (FMCG - sector includes dairies/petrol stations, food producers, supermarkets)

- Hospitality (specifically restaurants, bars, and cafes
- Trucking
- Building suppliers (wholesale and retail)
- Rural farm
- Rural non-farm (rural-farming organisations located proximal to the fault trace)
- Kaiapoi CBD
- Christchurch CBD (CHCH CBD)

This list is not a comprehensive representation of the economy of Canterbury. The breadth of the sample, however, means that the data extracted from this survey could be extrapolated to the wider economy of Canterbury due to sector inter-dependencies. ICT and rural farm are critical high-growth sectors. The trucking sector represents a critical link in the supply chains of many other industry sectors. FMCG and hospitality respectively represent non-discretionary and discretionary consumer spending. Lifelines and building suppliers represent sectors that are critical to the response and recovery of Canterbury organisations. The rural non-farm and Christchurch and Kaiapoi CBDs were included because of their significance to a community's day-to-day activities, and the possibility of analysing the spatial and network recovery factors of a large number of organisations concentrated in one physical area.

A.7 Results and discussion

A.7.1 Descriptive statistics

In total 869 organisations were contacted about the Organisational Resilience and Recovery survey. We received 376 responses representing a response rate of 42 percent. The locations of organisations that took part in the survey are shown in Figure A.1.

The sectors with the highest and lowest response rates were the ICT sector (55%) and rural farm (21%) respectively. The low response rate in the rural farm sample is believed to be in part an artefact of the sampling methodology, as not all organisations received

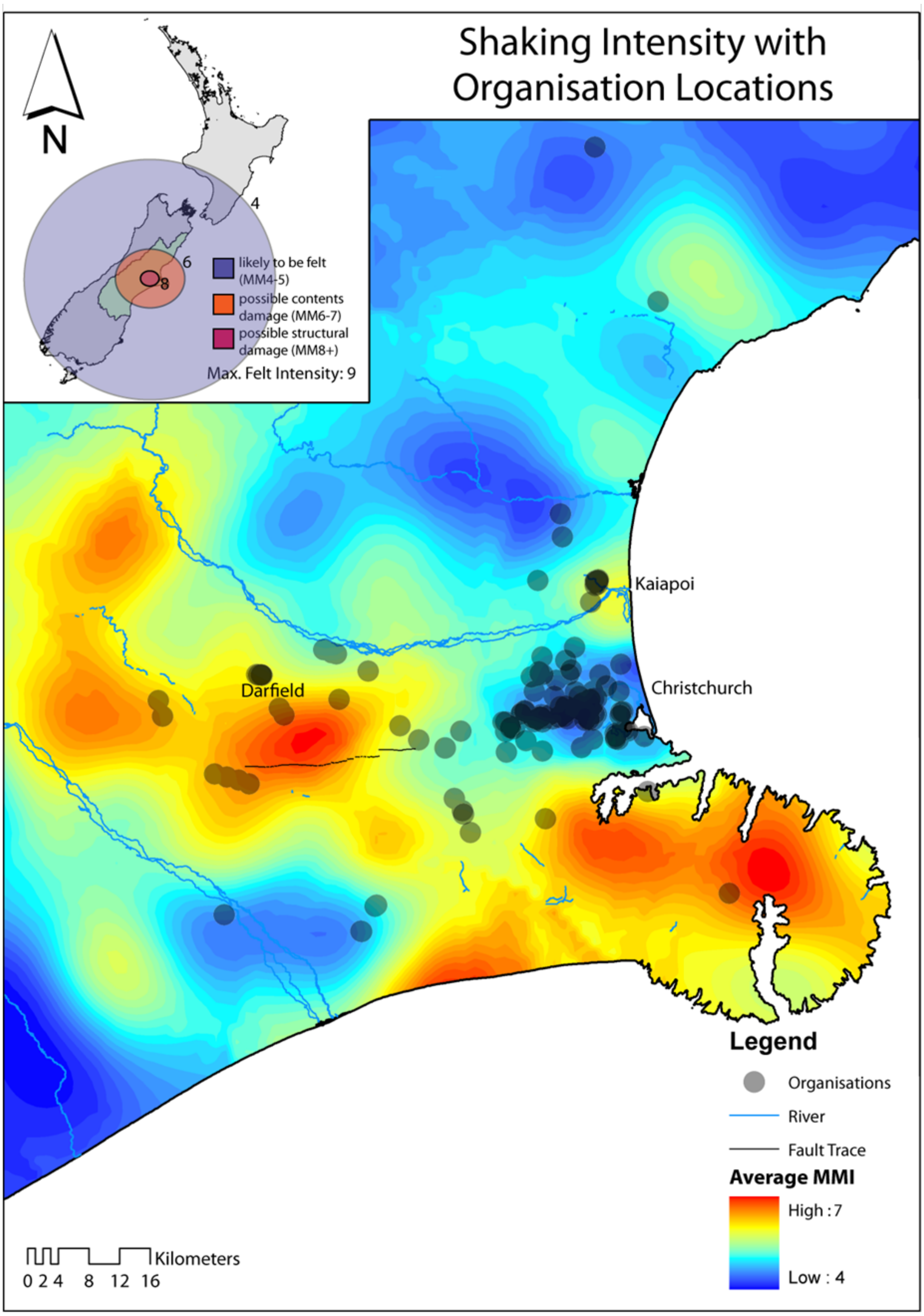

FIGURE A.1: Location of sampled organisations in relation to MMI intensities derived from GeoNet felt reports [203]. The isoseismal projection in the inset is derived from GeoNet [369]. In areas of low population densities, the intensity estimation is controlled by fewer data points while highly agglomerated areas are populated by many data points. Therefore, level the overall degree of shaking is represented with a large margin of error. The direction of greatest shaking occurred along the same direction of the surface fault line, and was also reported up the coast from Christchurch and at some locations on the Banks Peninsula. Although the scale MMI scale goes as high as MM12, note that the felt report questionnaire can only determine intensities up to MM 8. Intensities above MM 9 are usually determined by engineers who inspect damaged structures in some detail.

follow up calls due to an inability to collect contact details for these organisations . A complete sectoral breakdown of basic organisational information is found in Table A.1.

The distribution of organisation size in this study is generally reflective of the size of organisations throughout Canterbury and the rest of New Zealand. Most of the organisations in New Zealand are classified as small businesses (Welch, 2008). A large proportion (77%) of organisations sampled had fewer than 20 full-time employees, with a majority (51%) of the total sample employing fewer than five full-time staff. Organisations with greater than 100 full-time employees comprised 10 percent of the sample. A complete breakdown of sector attributes is shown in Table A.1.

Organisations were asked to report how long they have been in operation and the duration of operation in their current location. The majority of organisations (67%) have been operational for 10 years or longer. Respondents from lifeline organisations have operated, on average, longer than any other sector (80 years), while organisations in the hospitality sector reported the lowest average operational age (13 years). Similarly, lifeline organisations have a longer average duration of operations from their current location than any other sector (48 years) while organisations within the ICT sector have occupied their current location for the shortest period of time on average (9 years).

Duration of operation was positively correlated with the mean and median number of full time employees (r = .81, p = .005 and r = .72, p = .005 respectively) and the mean number of temporary staff (r = .64, p = .005). The older, more established organisations tended to be the largest employers. Organisations that rent the property from which they operate represented a majority (65%) of the sampled population. Only in two sectors (rural farm, and rural non-farm) did a majority of organisations own the property from which they operated.

Organisations that rent their premises do not have control over the building structure which in turn could affect their capacity to plan for their recovery.For instance, in one case, a building owner and organisation renting the premises in the Christchurch CBD disagreed on how long the building should have remained closed after the building was deemed safe for use. The organisation occupying the building was more focused on reopening after the building had been inspected while the building owner did not deem reopening an urgent priority, highlighting the conflicting priorities that may exist between building owners and renters.

Table A.1: Sample characteristics and per cent affected broken down by sector.

	Response Rate		Number of Employees Full		Part		Temp.		Years Operating		Years Operating At Location		Property Owner	Affected
Sector	N	%	$\bar{m}$	$\tilde{m}$	$\bar{m}$	$\tilde{m}$	$\bar{m}$	$\tilde{m}$	$\bar{m}$	$\tilde{m}$	$\bar{m}$	$\tilde{m}$	%	%
ICT	55	55	18	6	2	2	3	1	15	11	9	5	24%	56%
Hospitality	32	32	9	5	18	7	1	1	13	10	11	7	9%	94%
Trucking	38	38	31	10	9	2	1	1	33	24	17	13	45%	71%
Lifelines	24	55	233	112	41	13	192	4	80	100	48	28	54%	92%
FMCG	42	49	154	75	63	52	4	0	38	24	20	11	24%	88%
Build Supply	30	31	11	7	2	1	1	1	25	20	11	8	40%	70%
Rural non-farm	42	27	9	2	3	2	11	2	25	11	17	8	57%	88%
Rural Farm	30	21	35	2	2	2	1	1	34	28	26	19	93%	67%
CHCH CBD	33	45	15	3	29	3	2	2	35	30	16	12	6%	90%
Kaiapoi CBD	40	31	5	3	4	2	1	1	35	20	21	13	13%	90%
Total	366	36	46	5	17	3	26	1	31	19	18	10	35%	80%

Following the collection of basic organisational information (summarised in Table A.1), organisations were asked whether they had been affected by the earthquake.Overall, 80 percent of all organisations responding to the survey reported they were affected by the Darfield earthquake. If organisations felt that they had been completely unaffected by the Darfield earthquake, they were instructed to move to the end of the survey to complete the resilience thumb-print section. Therefore, all impact and mitigation data reported here are from organisations that reported they had been affected by the earthquake.

A.7.2 Impacts

Organisations were asked how disruptive were the following on your ability to do business? and provided with a list of potentially disruptive factors. The degree to which a factor was disruptive to an organisation was quantified using a 4-point Likert scale. The organisations were asked to rank earthquake-related disruption effects on a scale of not at all disruptive (assigned a score of 0) to very disruptive (assigned a score of 3). These scores were averaged across each sector, and then divided by the maximum score of 3 to calculate the severity of the disruption item for each sector. The factor score that ranges from 0-100 percent (0 percent indicating that all organisations found the factor to be not at all disruptive to their organisation and 100 percent indicating that all organisations found the factor to be very disruptive.) The results are presented in Table A.2.

No single factor proved to be consistently disruptive for all the sectors sampled. Organisations in the Kaiapoi CBD reported higher overall disruption across all items. The most disruptive item for Kaiapoi organisations proved to be damage to or the closure of nearby organisations. This was also the most disruptive item for organisations in the Christchurch CBD and the third most disruptive item for the hospitality sector. Organisations within the Kaiapoi and Christchurch CBDs, and hospitality sector also found the inability to access their site very disruptive on their ability to do business. These factors were cited as being more disruptive than structural damage to building. Interestingly, structural damage did not prove to be the most disruptive item for any sector sampled, though certain sectors indicated receiving more structural damage than others, as can be seen in Table A.2.

Table A.2: Average organisational disruption scores broken down by item and sector. Disruption scores above 50% (moderate to very disruptive) are shown in bold.

Sector	Structural damage to building(s)	Non-structural damage	Damage to equipment	Damage to computers	Damage to inventory or stock	Water supply disruption	Sewage or effluent disruption	Communications disruption	Damage to ground surface	Damage to or closure of adjacent organisations or buildings	Damage to or closure of nearby organisations	Unable to access site	Injury to employees	Other damage	Electricity disruption
ICT	17%	29%	17%	13%	12%	24%	11%	40%	10%	30%	32%	38%	0%	14%	40%
Hospitality	16%	22%	22%	5%	46%	36%	15%	16%	2%	**51%**	**52%**	**55%**	0%	4%	48%
Trucking	15%	15%	16%	7%	26%	11%	7%	23%	10%	6%	12%	4%	0%	7%	21%
Lifelines	23%	29%	24%	15%	16%	24%	18%	18%	18%	22%	15%	11%	0%	11%	30%
FMCG	21%	41%	26%	10%	**70%**	28%	18%	30%	11%	18%	31%	8%	4%	12%	39%
Buildings Suppliers	25%	22%	12%	8%	35%	6%	0%	13%	11%	13%	13%	6%	0%	11%	22%
Rural non-farm	23%	42%	34%	20%	42%	28%	10%	37%	8%	24%	25%	8%	2%	14%	**51%**
Rural Farm	38%	47%	47%	28%	28%	**58%**	27%	38%	22%	18%	17%	3%	0%	11%	**63%**
CHCH CBD	31%	31%	15%	9%	16%	17%	8%	33%	6%	**62%**	**64%**	**70%**	0%	17%	34%
Kaiapoi CBD	46%	26%	25%	13%	35%	**77%**	**69%**	**53%**	**53%**	**78%**	**83%**	**63%**	3%	20%	**63%**
All Groups	25%	31%	24%	13%	35%	32%	19%	31%	16%	34%	37%	28%	1%	12%	42%

Although it was not specifically asked about in the survey, organisations in the Christchurch and Kaiapoi CBDs and some of the organisations in the hospitality sector were located inside cordoned-off areas. As evidenced in the CBDs, organisations noted that even when they did not suffer any structural damages they were forced to close due to their proximity to unsafe buildings or due to their location in areas that were officially cordoned-off. This was not a significant issue for the majority of organisations outside of the CBD, highlighting the differences in risks assumed by organisations located within CBD areas [255]. In general, CBD areas have a higher proportion of older, historic buildings which are more vulnerable to earthquake damage [111]. Locating an organisation within the CBD offers the benefit of increased access to infrastructure, customers and other organisations, while increasing the exposure to damages from neighbouring structures and the likelihood to be located within a cordoned area. Workers and shoppers may also be put off by the perceived risk of multi-story building collapse in a future earthquake.

Organisations in the CBDs found that damage to or closure of nearby organisations was disruptive. They did not find the relationships with their neighbours to be as helpful in mitigating the effects of the disaster. Conversely, farm and rural non-farm organisations were not as affected by the closure of or damage to nearby organisations. Yet, they found their relationships with neighbours to be very helpful in mitigating the effects of the earthquake. Due to the limits of this study, these relationships were not examined in detail and further work is planned as part of the 2 year on-going study to understand the importance of network relationships and sectoral differences post-disaster.

The level of lifeline service interruption varied within sectors based on location. The major electricity distributor prioritised densely populated areas for the restoration of service, thereby slightly extending the period of power outage for the rural farm and non-farm sectors. Farming organisations especially show a significant difference in need for critical services and lifelines. For instance,dairy cattle require regular milking, otherwise the health of the livestock is compromised and the quality of milk is negatively affected. Livestock represent a significant investment for many farming organisations and are therefore exposed to loss during extended periods of lifeline service interruptions. Interruptions to lifeline services also proved very disruptive for organisations within the fast moving consumer goods FMCG sector as organisations with perishable items were especially sensitive to electricity and water outages. The FMCG and farming sectors are more dependent on rapid restoration of service as they have the potential to lose stock due to critical service disruption.

Organisations were also asked to report whether their organisation was relocated as a result of the earthquake. At the time of surveying, a large majority (92%) of affected organisations had not relocated. Twenty percent of organisations in the Kaiapoi CBD relocated, which represents one-third of all sampled organisations that relocated. This higher concentration of relocations in Kaiapoi might be due to the higher percentage of buildings in the Kaiapoi CBD that were damaged during the Darfield event compared to the Christchurch CBD.

Comparatively, only 10 percent of affected organisations sampled from the Christchurch CBD relocated. Approximately 16 percent of organisations within the ICT sector relocated. The majority of organisations within the ICT sector were forced to relocate due to non-structural damage or restricted access to their site. Other sectors that had at least one organisation relocate were trucking, FMCG, rural non-farm and rural farm.

The reasons for not relocating might vary for different sectors. For instance, no organisations in the hospitality sector relocated despite reporting high levels of damage. Barriers to relocation in the hospitality sector might include the nature of the equipment used, the customer base, as well as health and safety regulations. In contrast,the ability to relocate for ICT organisations may indicate that these organisations have more flexibility to relocate. From the respondents, the cited primary reason for the majority of organisations that relocated was building damage. However, three CBD organisations and one ICT organisation cited waiting for building assessments and an inability to access their building as a reason for relocating. For example, the ICT organisation reported that they relocated because their "office [was] within the cordon due to damage to adjacent buildings". Two organisations, one FMCG and one ICT, reported damage to non-structural elements as a reason for relocation.

Organisations that indicated structural damage to be highly disruptive were significantly more likely to have relocated. The disruptive effect of structural damage to organisations was highest in the Kaiapoi CBD sample, which as previously mentioned had the highest rate of relocation among the sample groups. Organisations in the ICT sector differed from this trend however in that the majority of relocations were not related to structural damage, but instead to site access and non-structural damage. Overall, the majority

TABLE A.3: Proportion of organisations affected organisations that closed, total sample that closed, and the length of closure per sector.

	Closed Organisations			Closure Length (days)		
Sector	N	% Affected	% Total	$\bar{m}$	*Stdev*	$\tilde{m}$
ICT	17	55	31	3	2	2
Hospitality	28	93	88	8	5	7
Trucking	8	30	21	11	24	2
Lifelines	9	41	38	4	2	3
FMCG	29	78	69	2	4	1
Buildings Suppliers	11	50	37	3	5	2
Rural non-farm	23	62	55	5	6	4
Rural Farm	1	5	3	2	0	2
CHCH CBD	29	97	88	9	8	7
Kaiapoi CBD	31	86	78	11	15	7
All Groups	186	64	51	7	10	4

of organisations did not experience significant structural damage which is part of the reason relatively few organisations relocated. However, it is unclear from these results whether more organisations were planning on relocating and had not yet done so at the time of sampling.

A.7.3 Closure

Of those organisations that were affected by the Darfield earthquake, the majority (63%) were forced to close for a period of time. A sectoral breakdown of these data is shown in Table A.3.

Of those organisations that reported closing for a period of time, the average length of closure was seven days. Organisations that were still closed at the time of sampling were excluded from the mean and median closure calculation. One organisation indicated that closure would be for 12 months while another organisation has restricted its operating hours to only the afternoons due to a drop in business activity. Three organisations indicated that closure was indefinite at the time of sampling. Organisations from the Kaiapoi CBD and trucking sector were closed for an average of 11 days, which was the longest period of time for all sectors.Many organisations included within the FMCG sample reported closing at some point for a period of approximately one to three days. Overall, the hospitality, lifelines, and rural farm sectors were the only samples that did not include at least one outlier or extreme value and were consequently the only sectors where the mean closure time was not right-skewed.The trucking sector specifically had one organisation reported closing for a period of 70 days, while the remainder of the sample was tightly grouped with a median closure length of 2 days.

The sample groups with the highest proportion of closures were within the Kaiapoi CBD (78%), Christchurch CBD (88%), and hospitality sector (88%). The sample groups with the lowest proportion of closures were farms (3%) and trucking (21%). The differences in closure proportions may be generally attributable to the location of the organisation (in terms of exposure to damage and cordons), but the nature of the business also plays a role. For example, farming organisations do not close in the traditional sense, while most hospitality organisations are unable to operate without electricity or water

The survey also asked organisations the reasons for closure following the Darfield event or subsequent aftershocks (between 17 November 2010 and 18 February 2011). Over half (58%) of affected organisations were forced to close because they were waiting for their building to be structurally assessed. This was the most commonly cited reason for the closure of organisations within the following sectors: Christchurch CBD (80%), ICT (92%), and Kaiapoi (64%). The second most common reason (50% of respondents) for closure was the need to clear up damage to the interior. The sectors to cite clear up damage to interior as the reason for closure most frequently were FMCG (77%) and rural non-farm (79%). The majority of organisations in the FMCG sample also cited stock loss or damage as a reason for closure.

Table A.4 shows correlations between different reasons for closure and highlights the strength and directionality between these reasons. The most commonly cited reason for closure, building waiting to be structurally assessed, was negatively correlated to the second most commonly cited reason for closure, needed to clear up damage to interior ($r = -0.73$, $p < .05$). Reasons for closure that were related to structural damages were positively correlated with one another. Non-structural reasons for closure were negatively correlated to structural damages. These relationships identify that the reasons organisations have for closing following the earthquake fall under two discrete categories: closure due to structural and non-structural damage. Organisations that reported not being able to obtain replacement supplies or materials also reported not being able to deliver supplies/services to customers. This shows the effect of disruption to the supply chain.

Table A.4: Correlations of reasons for closure. Only values significant to $p < 0.05$ are shown.

	Building waiting to be structurally assessed	Building declared unsafe	Building waiting to be repaired	Needed to clear up damage to interior	Needed to clear up damage to exterior	Machinery loss or damage	Stock loss or damage	Office equipment loss or damage	Damage to immediate locality	Could not obtain replacement supplies or materials	Could not deliver supplies/services to customers	Employees unable to get to work
Building waiting to be structurally assessed	1											
Building declared unsafe		1										
Building waiting to be repaired		0.64	1									
Needed to clear up damage to interior	-0.78	-0.7		1								
Needed to clear up damage to exterior	-0.81				1							
Machinery loss or damage	-0.79			0.73	0.93	1						
Stock loss or damage							1					
Office equipment loss or damage	-0.75		-0.66		0.84	0.87		1				
Damage to immediate locality							-0.7		1			
Could not obtain replacement supplies or materials							0.67		-0.62	1		
Could not deliver supplies/services to customers							0.6	-0.65	-0.84	0.7	1	
Employees unable to get to work					0.76	0.79	-0.61	0.7 7	0.73		-0.76	1

Table A.5: Summary of revenue changes per sector.

	Revenue Decreases			Revenue Increases		
Sector	N	$\bar{m}$ Decrease	*Stdev*	N	$\bar{m}$ Increase	*Stdev*
ICT	6	30%	13%	2	20%	14%
Hospitality	18	28%	12%	5	13%	4%
Trucking	9	25%	15%	4	22%	7%
Lifelines	1	35%	0%	3	23%	23%
FMCG	5	7%	8%	5	19%	12%
Buildings Suppliers	11	30%	20%	2	30%	14%
Rural Non-farm	14	40%	27%	3	75%	109%
Rural Farm	1	2%	0%	0	0%	0%
CHCH CBD	21	37%	22%	1	15%	0%
Kaiapoi CBD	22	40%	31%	3	18%	4%
All Groups	108	33%	23%	33	23%	33%

A.7.4 Network effects

The majority of organisations within the Kaiapoi and Christchurch CBDs as well as the hospitality sector experienced changes to their customer base. Within the Kaiapoi CBD sample, 31 percent of organisations reported a 'substantial' decrease in customer numbers while 23 percent reported 'moderate' decreases. In the Christchurch CBD sample, 48 percent of affected organisations reported 'substantial' decreases in their customer base, with another 34 percent experiencing moderate decreases. Within the building suppliers sector, 29 percent of affected organisations experienced substantial decreases in their customer base, while 57 percent reported no change.The lifelines sector saw a substantial increase in their customer base, which is largely attributable to the organisations that deal with waste management having increased workload due to debris removal.

Organisations were asked whether their revenue increased, decreased, or did not change following the Darfield earthquake. At the time of sampling, the majority (61.5%) of organisations had observed no change to their revenue as seen in Table A.5. Of those reporting a change in revenue, the effect was largely negative. The Christchurch CBD, Kaiapoi CBD and hospitality sector had the greatest number of organisations reporting revenue loss. Overall, the organisations reporting the greatest percent drop in revenue are within the CBDs and the rural non-farm sector. Lifelines and FMCG reported modest gains in revenue.

Organisations were asked to forecast how long they thought the earthquake would continue to affect their revenue. Thirty-eight percent of affected organisations responded that the effects of the earthquake on their revenue had ended by 30 September 2010. The second most commonly reported expected duration for revenue change (19% of organisations) was that it would continue for more than a year's time from 4 September 2010.In contrast, only 3 percent of responding organisations indicated that changes in revenue would persist for approximately 1 years' time which was the least commonly expected duration for revenue change.

In general, more organisations hired staff than made staff redundant in the five months following the Darfield earthquake. In total, sampled organisations affected by the Darfield earthquake made 13 full time, 17 part-time, and 4 temporary employees redundant in the aftermath of the earthquake, while 103 full-time employees, 146 part-time, and 73 temporary employees were hired. Organisations were not asked to specify whether redundancies and hires were due to the earthquake, however many organisations that reported redundancies identified the reasons for this were not due to the earthquake but were a result of normal business cycle. The FMCG and lifeline sectors took on the largest number of additional staff, which is most likely due to the heavy demand placed on these sectors in the aftermath of the earthquake. For example, waste management organisations in the lifelines sector had increases in their customer base. These organisations hired several temporary employees post-earthquake to service the increased demand. Throughout the lifelines sector, temporary and contract workers represented the majority of hires following the earthquake, which is most likely attributed to the demand to make a large number of repairs quickly.

On the other hand, the building suppliers sector had not yet seen the economic boom that they had been expecting post-earthquake. Only 37 percent of organisations within the building suppliers sector closed for any period of time following the earthquake. Yet, a majority of affected buildings suppliers reported a loss in revenue following the earthquake, with an average decrease of 30 percent. Organisations in this sector also cited forecasting demand and waiting for customers to get insurance settlements as their biggest challenges post-earthquake.

The majority of affected organisations (67%) reported using cash flow as a means to finance recovery. In the ICT and building suppliers sectors over 90 percent of organisations identified cash flow as a means for recovery. Insurance was the second most common overall source of financial recovery, which was most commonly cited by the rural farm, hospitality, and FMCG sectors. Approximately 12% of reporting organisations cited using the Earthquake Support Subsidy (ESS) as a means to finance recovery. The majority of affected organisations held insurance policies for organisational interruption, property and buildings, organisational assets, motor vehicles, public liability, and commodities. Certain sectors, such as the rural farm, lifelines, ICT, trucking and FMCG relied almost entirely on cash flow, savings and insurance to finance their recovery.

Sample groups that relied on a variety of alternative means to finance recovery, such as borrowing money from family or friends, bank loans and credit cards, were the Christchurch CBD, Kaiapoi CBD, building suppliers, and hospitality. In financing recovery efforts, large positive correlations exist between sample groups that used money borrowed from friends and family and organisations that used credit cards ($r = 0.92$, $p < .05$), as well as bank loans ($r = 0.96$, $p < .05$). Respondents that relied on bank loans for recovery financing also showed strong correlations to the use of credit cards ($r = 0.91$, $p < .05$). The sample groups that relied on organisational cash flow were unlikely to rely on their savings ($r = -0.83$, $p < .05$) or their insurance claims ($r = -0.80$, $p < .05$).

A.7.5 Mitigation factors

Organisations were given a list of 14 potential factors that helped contribute to mitigating disruption to operations. Using a 4 point Likert scale ranging from not at all to very helpful, these organisations were asked to identify each factor's usefulness. These factors were then averaged at the sectoral level and divided by the total possible score to ascertain a sector mitigation factor score that ranged from 0-100 percent (0 percent indicating that all organisations in a sector found the factor to be not at all helpful in mitigating the effects of the earthquake and 100 percent indicating that all organisations found the factor to be very helpful).

The factors that organisations found most helpful in mitigating disruption to operations after the Darfield earthquake were (in order of reported helpfulness in mitigating the effects of the earthquake):

- well-designed and well-built buildings;
- relationship with staff; and
- critical services being restored quickly or were not interrupted.

The two most important factors to the majority of sectors were either well designed and well-built buildings or the relationship with staff. On average across all sectors the design and build of the buildings was reported to be the most helpful factor in mitigating disruptions. Although at the sectoral level, the lifelines, FMCG, and Kaiapoi CBD samples identified relationship with staff to be the most important mitigating factor.

Organisations that utilised resources other than their organisation's cash flow found available cash or credit to be a helpful factor in mitigating the impact of the earthquake. Farm and rural non-farm organisations indicated that their relationships with neighbours were helpful in mitigating the effects of the earthquake, while other sectors found this to be less important to their mitigation strategy. Complete sectoral results of the mitigating factors are shown in Table A.6.

Strong correlations exist between certain mitigating factors. For example, organisations that found practised response to disaster helpful in mitigating organisational disruptions also found business continuity, emergency management or disaster preparedness plans helpful ($r = .97$, $p < .05$). Additionally, organisations that found business continuity, emergency management or disaster preparedness plans helpful showed a large positive correlation with the number of full-time employees. A complete table detailing all significant correlations ($p < .05$) is shown in Table A.7.

Larger organisations were significantly more likely to have found business continuity plans to be helpful in mitigating organisational disruptions. In addition, organisations that had practised responses for disasters indicated that these drills were helpful in mitigating organisational disruption. However, only in the lifelines and FMCG sectors did a majority of affected organisations indicate that practised responses for disasters were moderately to very effective in mitigating the effects of a disaster. These data show that organisations with business continuity, emergency management, or disaster preparedness plans find these plans useful, and believe these plans to be more effective when these plans are rehearsed. Furthermore, the lifelines sector found the rehearsal

TABLE A.6: Sectoral results of the mitigation factor scores per item. Mitigation factor scores above 50% (moderately to very helpful) are shown in bold.

	Backup/alternatives to critical lifelines	Critical lifelines restored quickly/not interrupted	Relationship with staff	Relationship with banks or lenders	Relationship with our neighbours	Available cash or credit	Spare resources	Insurance	B.C./emerg.mgmt/disaster preparedness plan	Backup or alternative site	Practiced response to a disaster	Emergency kit	Well designed and well-built buildings	Other (please specify)
ICT	24%	**64%**	**68%**	21%	24%	43%	18%	13%	40%	29%	33%	18%	**71%**	33%
Hospitality	17%	**60%**	**75%**	**51%**	49%	**60%**	27%	**54%**	20%	8%	5%	7%	**81%**	44%
Trucking	14%	**52%**	**60%**	27%	24%	31%	33%	36%	24%	13%	19%	21%	**65%**	29%
Lifelines	**55%**	**76%**	**87%**	11%	22%	35%	**64%**	33%	**83%**	33%	**79%**	**53%**	**83%**	**100%**
FMCG	23%	**60%**	**82%**	30%	24%	43%	47%	**51%**	**61%**	29%	**52%**	32%	**75%**	40%
Buildings Suppliers	18%	47%	**63%**	32%	19%	35%	11%	26%	18%	9%	16%	16%	**77%**	0%
Rural Non-farm	41%	**69%**	**67%**	41%	**67%**	**52%**	43%	**51%**	32%	9%	29%	32%	**78%**	**52%**
Rural Farm	**52%**	**67%**	42%	32%	63%	**53%**	**55%**	**65%**	35%	17%	28%	**52%**	**85%**	10%
CHCH CBD	18%	47%	**69%**	32%	45%	**55%**	26%	40%	37%	27%	24%	21%	**69%**	**67%**
Kaiapoi CBD	41%	49%	**72%**	**52%**	**50%**	**60%**	39%	47%	39%	34%	24%	17%	**59%**	0%
All Groups	30%	**59%**	**69%**	34%	40%	47%	36%	42%	39%	21%	31%	26%	**74%**	32%

TABLE A.7: Correlations of mitigating factor scores analysed at the sector level. Values shown are significant to $p < 0.05$.

	Backup/alternatives to lifelines	Lifelines were restored quickly or not interrupted	Relationship with staff	Relationship with banks or lenders	Relationship with our neighbours	Available cash or credit	Spare resources	Insurance	B.C./Emerg.Mgmt/disaster preparedness plan	Backup or alternative site	Practiced response to a disaster	Emergency kit	Well designed and well-built buildings	Other (please specify)	Mean number of employees	Median number of employees
Backup/alternatives to lifelines	1															
Lifelines were restored quickly/not interrupted	0.68	1														
Relationship with staff			1													
Relationship with banks or lenders				1												
Relationship with our neighbours					1											
Available cash or credit				0.79	0.8	1										
Spare resources	0.79	0.68					1									
Insurance					0.74			1								
B.C./Emerg.Mgmt/disaster preparedness plan							0.72		1							
Backup or alternative site									0.75	1						
Practiced response to a disaster		0.65		-0.7			0.7		0.97	0.64	1					
Emergency kit	0.8	0.71					0.86		0.68		0.74	1				
Well designed and well-built buildings		0.67											1			
Other (please specify)									0.65					1		
Mean number of employees				-0.64			0.69		0.91		0.93	0.66			1	
Median number of employees			0.69						0.9		0.91				0.99	1

of emergency response plans to be more helpful than the plan itself, indicating that emergency management plans may be of secondary importance to the rehearsal and review of these plans.

The only sector that found relationship with staff relatively unimportant in mitigating the effects of the earthquake was rural farm. Instead, rural farms identified backup/alternatives to water, sewerage, electricity, communications to be an important factor in mitigating the impacts of the earthquake as the health of livestock was dependent on these services. Comparatively, the FMCG sector, which was heavily affected by damage to inventory or stock, did not report backup/alternatives to water, sewerage, electricity, communications to be especially important in mitigating the impacts of the earthquake. Organisations within the FMCG sector found the rapid restoration or continuity of utility services to be more important. This is partially related to the fact that the rural communities have longer critical service disruption periods when compared to more densely populated areas, and thus would be more reliant on alternatives to critical services for longer periods of time.

Government support programs following the Darfield earthquake were made available to organisations. Examples of direct governmental support available include the Canterbury Business Recovery Trust Fund, Individual Support Payments, the Earthquake Support Subsidy, Rural Support Payments and tax relief and extension options. There has been substantial uptake of the support subsidy program by businesses. For instance, the New Zealand Department of Labour found over 50% of sampled businesses had received wage subsidies, which totalled $10.6 million in pay-outs to 2,800 businesses from 4 September to 1 November 2011 [370, 371]. Official sources noted these subsidies to be helpful to the majority of organisations that received the assistance [371]. Additionally, support helplines, information databases and business mentors were made available at no cost to organisations [372].

A.7.6 Biggest challenges

Organisations were asked what the biggest challenges were following the earthquake, the results of which were grouped by sector. For all the sectors, the majority of respondents cited staff wellbeing as a challenge for operations following the Darfield earthquake. All other major challenges cited by organisations are broken down by sector in Table A.8.

Table A.8: Summary of each sectors biggest challenges in the aftermath of the 4 September earthquake.

Sector	Biggest Challenges
ICT	Increased demand for services
	Relocations and access issues
	Difficult to access customers in city
Hospitality	Staff availability
	Cash flow & supply chain & decrease in customer numbers
	Customers not spending
	Access to sites
Trucking	Forecasting demand
	Preparedness, planning for crisis
	Logistics (especially storage) & lower sales
Lifelines	Inspection of equipment
	Continuing work started before EQ
	Shutdown/restarting operations
	Increase in demand
FMCG	Stocking issues
	Supply chain
	Non/structural damage
Building suppliers	Forecasting demand
	Sales down from waiting for rebuilding work to start
	Lack of customers
Rural non-farm	Cash flow & drop in revenue
	Lower customer number & customers spending less
	Supply chain & logistics
Rural farm	Lifelines disruption
	Structural repairs
Chch CBD	Customers' perceptions of Chch CBD as not open
	Accessing site
	Customer spending, cashflow, revenue
Kaiapoi CBD	Lack of customers/customers not spending
	Relocation
	Access to site & structural damage

Organisations identified a breadth of challenges relating to staff management including: stress and fear in staff, loss of productivity, and decreased focus. In the Kaiapoi

CBD, organisations cited part of the reason for decreased productivity was customers occupying staff time relating their earthquake experiences. One organisation is quoted as saying their biggest challenge was, the amount of time spent with customers and staff talking and counselling about the effects of the earthquake on them. Some people want to talk about it a lot. Both the Christchurch and Kaiapoi CBDs identified public perception of the CBDs as being off-limits as well as site and road inaccessibility as significant challenges to their organisations even when organisations were fully operational. Organisations also believed that damage to and cordons around nearby organisations kept potential customers away.

A.8 Conclusions

The results from this study identify the direct and indirect physical, spatial, and network impacts to organisations after the Darfield earthquake. Resilient organisations mitigate the physical, economic, and social impacts of a crisis by consistently preparing for and adapting to their hazardscape. This study has aimed to catalogue the initial impacts of the Darfield Earthquake across a range of sectors to appraise the overall disruption to organisations, identify controlling factors based on organisational characteristics, and contextualize the organisational recovery. This study also lays the foundation for future data captures in the months following to better understand organisational resilience.

While the strong ground motion forced a majority of organisations to close due to some level of direct physical damage such as liquefaction, non-structural damage, stock loss, and prevented site access to name a few there was a wide variety of disruptive impacts related to the earthquake, and all industry sectors showed unique sensitivities. Many organisations belonging to the same industry sector were impacted in similar ways, which in part are related to industry-wide vulnerabilities such as barriers to relocation or carrying of perishable stock. The resources organisations relied on to mitigate the effects of the earthquake also showed some sectoral patterns, illustrative of the inherent resilience sectors have to the effects of earthquakes.

These results highlight some degree of sector-level resilience to the effects of the Darfield earthquake by identifying the affected organisations vulnerabilities. For instance, organisations located in Central Business Districts (CBDs) showed a high vulnerability to structural damage, damage to neighbouring buildings, inability to access their premises, and public mis-perception. These results are consistent with the findings of previous studies from the United States [110, 125]. Farming organisations were vulnerable to damage to buried infrastructure, fence lines, and operation infrastructure such as dairy sheds. Dairy farming was especially vulnerable to critical service interruption. The FMCG sector was also highly vulnerable to critical service outages; however, these losses appeared to have been offset by increased demand in the days following 4 September. Instead, the primary vulnerability for this industry was predicting and keeping up with demand for certain products while also minimising losses from non-structural damage. The lifeline sector was most vulnerable to physical damage to infrastructure.

Rural organisations, even those close to the fault trace, did not show significantly higher levels of disruption due to physical damage when compared to organisations in Christchurch and Kaiapoi. This suggests that other processes, such as liquefaction which was a large contributor to organisational disruption in many parts of Kaiapoi complicate the pattern of disruption observed. Central business district, fast moving consumer goods (FMCG), rural non-farm and hospitality sectors were most likely to have been forced to close and for the greatest period of time while farming organisations were least likely to close.

At the time of sampling (2 to 5 months following the event), 61.5% of organisations reported no change to their overall revenue. The percent of organisations reporting changes in revenue were slightly lower than to the findings of Chang and Falit-Baiamonte [111]; however this difference is likely due to the fact that, among a variety of contextual differences, medium and long-term loss data were not available at the time of sampling. Organisations which reported the greatest decrease in revenue were from the Christchurch CBD, Kaiapoi CBD and the hospitality sector. Rural farm, lifeline and FMCG reported modest increases. Building supplies organisations largely had not seen increases in the demand for goods/services, which was widely anticipated following the structural damages observed.

Factors which organisations reported as being most effective at mitigating disruption included well-designed and well-built buildings; relationship with staff; and critical lifeline services being restored quickly or not interrupted. Organisations showed a large reliance on built-infrastructure such as building integrity, highlighting the importance of strong building codes as well as a potential area of improvement through the use of alternative means of data management such as cloud computing, or telecommuting availabilities. Organisations also showed a heavy reliance on lifeline services, and developing back-up alternatives is another potential area for improvement for a large variety of sectors.

All of the earthquake-related impacts were not yet manifest at the time of sampling and it is the intention with this research to follow these organisations for a period of 18 months to 2 years to identify what medium-term effects may exist. However, due to the 22 February and 13 June, 2011 earthquakes which caused significantly greater impacts to the Christchurch built and social environments, the research will need to again sample affected organisations to gather preliminary impact data specific to these new events, while also gathering more in-depth information as part of the study.

The study will seek to understand how an organisation's pre-earthquake characteristics, including its level of resilience, affect its ability to recover and adapt to new economic and social environments post-earthquake. The study will also investigate the unique challenges faced by organisations within CBDs, some of which have been highlighted by the preliminary results presented in this appendix chapter. Further, the role of networks, business models and supply chains in recovery will also be examined.

A.9 Acknowledgements

The authors gratefully acknowledge funding from the New Zealand Natural Hazard Research Platform (NHRP), Ministry for Agriculture and Forestry (MAF), Ministry for Civil Defence and Emergency Management (MCDEM), and the University of Canterbury Mason Trust. We thank Hai Sue Kang, Kathryn Bates, Rachel McConnell, Amy Hall, Jonathon Pettigrew, Hosai Najib, Lara Hawke, Christian Ruegg, Mark Letham and Sarah Standring for assisting with telephone interviews. We acknowledge the New Zealand GeoNet project and its sponsors the Earthquake Commission (EQC), GNS Science and Land Information New Zealand (LINZ), for providing data/images used in this study. Thank you to the two anonymous reviewers for their valuable and supportive comments. Finally, we gratefully acknowledge the time and effort taken by respondents who chose to participate in this study. This research is part of the Resilient Organisations research programme which has initiated a longitudinal study of organisations

affected by the Canterbury earthquakes. Results from the programme will be made available via the organisations website: www.resorgs.org.nz.

Appendix B

Short-Form version of the Benchmark Resilience Tool (BRT-53)

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B.1 Overview

This chapter outlines the methodology in developing a short-form version of the BRT-53 questionnaire, which was first deployed in the Hurunui district as explained in Chapter 2. The short-form version of the BRT-53 described in this chapter was used in all questionnaires deployed to organisations during the Canterbury earthquake sequence as well as the 2010 Southland snowstorm. It was included to capture quantitative organisational resilience data, the results of which ultimately falls outside the scope of this thesis.

B.2 Contributions

Mr. Whitman and Ms. Kachali developed the concept for the paper and collected the requisite data. Mr. Whitman and Ms. Kachali both provided data sets derived from questionnaires developed in collaboration. Mr. Whitman performed the analysis, and both Mr. Whitman and Ms. Kachali developed the manuscript. Dr. Roger reviewed and offered comments on Mr. Whitman's and Ms. Kachali's interpretation of the results. Dr. Vargo and Dr. Seville supervised the process and provided comments on the manuscript.

B.3 Abstract

The Benchmark Resilience tool (BRT-53) is an organisational-level resilience quantification methodology which assesses behavioural traits and perceptions linked to the organisation's ability to plan for, respond to and recover from emergencies and crises. The BRT-53 is a survey with 53 questions (items) that yields a 13 scale profile or organisational resilience based on 13 theoretical constructs. Items are drawn from the BRT-53 to create two shorter forms of the tool using two different methods for comparative purposes. The first method involves the selection of items based on the 13 theoretical constructs used in the development of the original tool. This shortened index is called the BRT-13A. The second method derived 13 items from the theoretical constructs using statistical correlations of the items within each construct. This shortened index is called the BRT-13b. The scores from each short-form index were computed into overall resilience scores that were then compared with the overall resilience scores generated from

the BRT-53. The results of these comparisons found that both the BRT-13A and BRT-13b produced valid and reliably similar results to the BRT-53. The BRT-13b proved to be slightly more valid and reliable than the BRT-13A and is recommended over the BRT-53 as the short-form version significantly decreases the likelihood of survey fatigue and low response rates with very little sacrifice to survey validity or reliability.

B.4 Introduction

Organisational resilience is an organisation's ability to plan for, respond to and recover from emergencies and crises [373–375]. As some organisations are more resilient than others [376], the identification of common characteristics among resilient organisations has yielded a body of literature that supports several theoretical constructs that contribute to resilience. Increasing organisational capacities within these different theoretical constructs of resilience are predicted to improve organisational survival following different types of crises. Utilising these theoretical constructs of resilience,the Benchmark Resilience Tool (BRT-53) was developed to benchmark an organisational resilience, regardless of industry sector or organisational size [83, 120, 238].

Given the importance of resilience for organisations, there are surprisingly few tools for the measurement of its theoretical constructs. Of the few tools that have been developed, resilience is assessed from specific perspectives such as size, industry or other particular aspects of the organisation. For example, the CERT Resilience Management Model (CERT-RMM) [377], the Resilient Institute's [378] Resilience Diagnostic, and the Magus Indexer [379] are all designed with a specific theoretical framework and end-user in mind. The CERT Resilience Management Model (CERT-RMM) [377] is targeted towards organisational resilience from an information and communication technology (ICT) security perspective. The Magus Indexer [379] was developed for use by organisations with at least 100 people. In other work, the Resilient Institute's [378] Resilience Diagnostic is more focused on the resilience of the individuals in the organisation as opposed to the resilience of the whole organisation. Other resilience measurement tools include those by the Stockholm Resilience Centre for the resilience of socio-ecological systems [380] as well as the Community and Regional Resilience Institute's (CARRI) measure of community resilience [381]. These methodologies, while effective within their respective domains, are not broadly applicable to the majority of organisations and lack the ability to compare across domains and organisational sizes. Consequently, as an alternative to these highly specialised tools, the BRT-53 was designed to be used to measure resilience in a wide range of organisations, regardless of size or industry sector. Additionally, the BRT-53 can be used in concert with some of the other resilience measurement tools mentioned such as the Resilience Institute's Resilience Diagnostic [378]. The BRT-53 can be deployed using different media formats (e.g. online or as a paper questionnaire) and as a self-administered questionnaire is convenient for respondents to use. Results from the use of the BRT-53 can then be used as a starting point for the organisation to investigate how they can improve their resilience.

The focus of this appendix chapter is on the development and validation of a short-form of the BRT-53. The authors focus on the BRT-53 as a tool for the measurement of organisational resilience stems from their experience using the tool in the greater Christchurch region following the 2010-2011 series of devastating earthquakes [254, 382], as illustrated in Chapters 3 - 5 and Appendix A. This deployment of the tool brought to light some challenges of the BRT-53 in its current form as well as opportunities for improvement. One of the challenges of using the BRT-53 was the length of the survey questionnaire (53 items) especially when coupled with questions designed to investigate other phenomena such as effects of the earthquakes in the greater Christchurch area. This led to survey respondents reporting the combined questionnaire as being too long. Consequently it was recognised that a short-form of the BRT-53 would improve usability and response rates even when used on its own.

In this appendix chapter, the Benchmark Resilience Tool (BRT-53) is introduced and its theoretical basis is discussed. Then, a short-form methodology is developed and assessed through measures of reliability and validity, taking statistical and theoretical considerations into account for the selection of representative items. Finally, the application, advantages and limitations of the short-form survey are outlined.

B.5 The BRT-53 development and model

The Benchmark Resilience Tool (BRT-53) tests the practical application of the theoretical constructs identified as making up organisational resilience. The basis of the BRT-53 was developed from the qualitative work of McManus [238] who investigated the resilience of organisations in New Zealand. McManus [238] identified 15 indicators of organisational resilience grouped under three factors. Stephenson [83], building on the work of McManus [238], then developed a quantitative methodology that measured the indicators of organisational resilience. This later work of Stephenson [120] and Lee et al. [78] led to the current form of the BRT-53. Using exploratory factor analysis (EFA) techniques, 53 items are constrained by 13 theoretical constructs defined as indicators that are found to be constituents of a two-factor model of organisational resilience. The two latent factors are named: adaptive capacity and planning. The indicators within each of the factors and the number of items per indicator are illustrated in Table B.1. Table B.1 also shows the Cronbach's Alpha values for each of the indicators.

Table B.1: Structural breakdown of the factors of organisational resilience, showing the indicators, the number of questions per indicator, and the internal reliability of the 13 indicators used to form the latent variables. From the table it is evident that all reliabilities are 0.68 or higher, indicating strong internal reliability.

Organisational Resilience Factor	Indicator Code	Indicator Description	Items	Cronbach's Alpha
Planning	P1	Proactive Posture	5	0.70
	P2	Recovery Priorities	4	0.82
	P3	Planning Strategies	4	0.68
	P4	Participation in Exercises	3	0.79
	P5	Capability & Capacity of External Resources	4	0.74
Adaptive Capacity	AC1	Internal & External Situation Monitoring & Reporting	7	0.82
	AC2	Capability & Capacity of Internal Resources	3	0.72
	AC3	Staff Engagement & Involvement	2	0.71
	AC4	Silo Mentality	4	0.76
	AC5	Information & Knowledge	5	0.75
	AC6	Leadership, Management & Governance Structures	6	0.83
	AC7	Innovation & Creativity	3	0.72
	AC8	Devolved & Responsive Decision Making	3	0.73

Adapted from Stephenson (2010)

All the items within the BRT-53 model are 4-point Likert-scale questions that assess the organisations agreement with individual statements. Because each indicator contains a different number of items, all the indicators were equally weighted before being used to calculate the adaptive capacity and planning factor scores. As pointed out earlier, the BRT-53 is a self-administered questionnaire that provides organisations with an indication of their performance for each of the 13 areas of organisational resilience. The difference in results from use of the BRT-53 at different times makes it possible for organisations to assess themselves and make improvements. A detailed discussion of the development process, the theoretical basis for the 13 resilience constructs, and results from the original development of the BRT-53 are found in Stephenson [83] or Lee et al. [78].

B.5.1 The need for a short-form version

As part of continual development of the BRT-53, deployment in the greater Christchurch area following the 2010-2011 series of earthquakes showed that a practical limitation of the 53-item scale was a significant commitment in time and energy for the respondents. For instance, for some respondents the number of items alone made them reluctant to use the tool. Other respondents felt that some of the items were redundant. Yet other survey respondents advised that a shorter, more targeted version would likely encourage participation. The BRT-53 also saw relatively high item omission rates or item inapplicability for small- to medium-sized organisations (SMEs). For example, some of the items in the BRT-53 ask about how different departments in the same organisation work together. Respondents from some small- to medium-sized organisations pointed out that their organisations were not arranged into multiple distinct departments. In addition, the BRT-53 proved difficult to deploy in conjunction with additional lines of questioning (e.g. to assess impacts of disaster on organisations) as this led to even longer surveys. As short-form versions have previously been developed to decrease survey time and improve response rates without significant losses in data validity and reliability [383–385], the development of a short-form version of the BRT-53 was found to warrant further analysis.

B.5.2 Short-form validation and reliability

The quality of a questionnaire survey, and consequently the short-form version can be evaluated by analysing its validity and reliability [386]. Validity concerns the content of the concept being measured; or in other words, is the concept described the one being measured? For the purposes of this appendix chapter, two forms of evidence are used assess validity. The first is by measuring the correlations of indicator, factor and overall scale scores generated from different measures [387, 388]. The second is through the reliability of the overall scale as well as the constituent factors. Reliability is the consistency of the tool, evaluated by measuring a concept at various times and then analysing the internal consistency of the items. Reliability can be established by comparing with other validated methods of measurement of an equal or a higher level. For instance, the reliability of a short-form survey can be tested by comparing results to those of an already existing standardised and validated questionnaire [389]. Cronbach's alpha [390], a measure of the homogeneity of a group of items in a questionnaire is often used for evaluation of internal consistency [391]. Other short-form versions of questionnaires that have been developed and tested using one or other of the above techniques include the General Health Questionnaires (GHQ-12, GHQ-28) [383], the Medical Outcomes Study SF-36 [385] and the Parkinson Disease Questionnaire PDQ-8 [384].

B.6 Methods

The methodology to constrain the number of items began by analysing the 13 indicators internal reliabilities from Stephenson [83] and Lee et al. [78]. This was done because the BRT-53 is constructed using the equally weighted scores from 13 indicators, and the indicators exhibited high internal reliabilities, as shown in Stephenson [83]. Therefore, single items from each indicator should be accurate approximations of the theoretical constructs, and adequate representations of the two factors they constrain. Raubenheimer [392] advises that when using exploratory factor analysis (EFA) for item selection, each indicator should have a minimum of three items. This is to ensure consistency and validity. Two methodologies, theoretical and statistical, were tested to determine which item from each indicator was most representative.

The first method involved selecting items that best approximated the theoretical nature of each construct's critical components. A single item from each indicator was selected through a discussion panel of seven researchers. Prior to selection, each construct was outlined, and its major components defined. The most appropriate item per indicator was then selected by the research team who were all familiar with the model's theoretical constructs. This first short-form version developed was defined as the BRT-13a.

The second method used for item selection was based on the statistical correlation of each item to the overall construct score. The data used for this determination were the same data used in the development of the original BRT-53. All items were correlated to their respective indicator's average score, and the highest correlating item to the indicator's average score was selected. This second short-form version was named the BRT-13b.

While the BRT-13a and BRT-13b were arrived at using different selection criteria, for 6 of the 13 indicators the items in both short-forms were identical. For the remaining seven indicators that were represented using different items, the item-indicator correlations were compared to assess the differences between the two methods. The overall item-indicator differences between the item-selection methods were found to be relatively minor. As shown in Table B.2, the differences between the items selected in BRT-13a and BRT-13b do not exhibit large differences in their correlation to the indicator scores from BRT-53.

Table B.2: The correlations between the item and the corresponding indicator calculated from BRT-53 are shown for both the short-form surveys.

Factor	Indicator Code	BRT-13A to BRT-53	BRT-13B to BRT-53	Difference
Planning	P1	0.740	0.740	0.000
	P2	0.861	0.861	0.000
	P3	0.772	0.776	0.004
	P4	0.794	0.794	0.000
	P5	0.845	0.876	0.031
Adaptive Capacity	AC1	0.762	0.816	0.054
	AC2	0.842	0.842	0.000
	AC3	0.882	0.882	0.000
	AC4	0.695	0.743	0.048
	AC5	0.755	0.813	0.058
	AC6	0.797	0.831	0.033
	AC7	0.832	0.832	0.000
	AC8	0.671	0.777	0.106
	Average	0.788	0.814	0.026

For both short-form versions, BRT-13a and the BRT-13b, overall scores of organisational resilience were computed using the same method used to compute scores for the BRT-53. The overall resilience scores for both short-forms were then compared to the results generated from the BRT-53 and analysed for differences. The results were also then compared at the factor level.

Three datasets were used to compare the effectiveness of the BRT-13a and the BRT-13b in approximating the BRT-53: the Auckland dataset, the Hurunui dataset and the Canterbury dataset. These datasets were collected from organisations from three regions in New Zealand under different contexts. Also, the organisational industry sectors represented in each of the sample sets varied. The Auckland dataset was the original dataset, and served as the basis for the BRT-53. The other two datasets were collected following the development of the BRT-53.

For all three datasets, cases with missing values were removed to exclude any potential bias from missing value replacement methodologies. While it was observed that smaller organisations, most especially organisations within the primary industries, were more likely to omit items and consequently more likely to be excluded from the analysis, no significant change in the sampled population's organisational size distribution was observed following case removal.

B.7 Results

The first deployment, the Auckland dataset, was completed in 2009 by organisations in the Auckland region. The questionnaire was deployed to 1009 organisations, receiving responses from 249 individuals from 68 organisations [78, 83]. Over 70% of the responding organisations were from three sectors: property and business services, manufacturing, and wholesale trade. The remaining sample represented 10 different sectors. In terms of disaster context, the responding organisations were not in the aftermath of a significant regional crisis.

Overall resilience scores for each organisation were generated from the BRT-53, the BRT-13a and the BRT-13b. The distributions of these scores were assessed against normal distributions using Q-Q plots. The distributions of both short-forms show relatively similar shapes and locations as shown in Figure B.1. Scores from the BRT-13a showed higher case variance and therefore the tails of the distributions were accentuated. Consequently, use of the BRT-13a may lead to slightly more polarised results for organisations whose organisational resilience scores fall within the extreme bands of the distributions. The effect of the distortion increases with distance from the mean and extreme organisational resilience values are amplified when using both short-forms. However the discrepancy between these expected and observed organisational resilience values is small and the distributions are not significantly distorted. The BRT-13b short-form appears to replicate the shape of the population's distribution more accurately.

The second deployment, the Hurunui dataset, was completed in 2010 by organisations in the Hurunui District, an area largely populated by the primary producer sector. Of the 1002 organisations contacted, 71 organisations responded; respondents were instructed to return one response per organisation. Over 80% of sampled organisations were from three sectors: primary industries, retail trade, and accommodation and food services. Of that, the primary industries comprised 59% of all sampled organisations, by far the most represented sector. The remaining sample subset comprised eight other sectors. Organisations in the district had recent disaster experience, with drought conditions found in many areas of the district for multiple years and some recovering from two major flooding events that occurred in 2008.

Again, the two short-form survey results were compared against the full questionnaire using the distributions of each scales' overall resilience scores. As shown in Figure B.2, the distributions of both the BRT-13a and BRT-13b show similar shapes, and differentiating a superior methodology is difficult to judge visually. Likely due to the small sample size, the populations from the BRT-53, BRT-13a, and BRT-13b do not exhibit normal distributions. Similar to what was observed in the Auckland dataset, the BRT-13a and BRT-13b may potentially reward organisations that showed higher scores, however the discrepancy between the distributions is small.

The third deployment, the Canterbury dataset, was completed in 2011 for organisations that were sampled following the 4 September 2010 Darfield earthquake on the South Island of New Zealand. These organisations had already been contacted immediately following the event and the deployment of the BRT-53 was the second of three data captures designed to assess the Darfield earthquake's impact on organisations in the affected region. After case deletion, 66 organisations remained from those that took part in the BRT-53 questionnaire; each organisation completed one instance of the questionnaire.

As shown in Figure B.3, for Canterbury the distributions of the BRT-13a and BRT-13b appear to match closely that of the BRT-53. Dissimilar to the results from the Hurunui dataset, the residuals for both the BRT-13a and BRT-13b populations when compared to BRT-53 are more normally distributed for the Canterbury dataset. Additionally, the BRT-13b may exhibit a slight negative bias when compared to the results of the BRT-53. Differences between the two short-form results are difficult to determine visually.

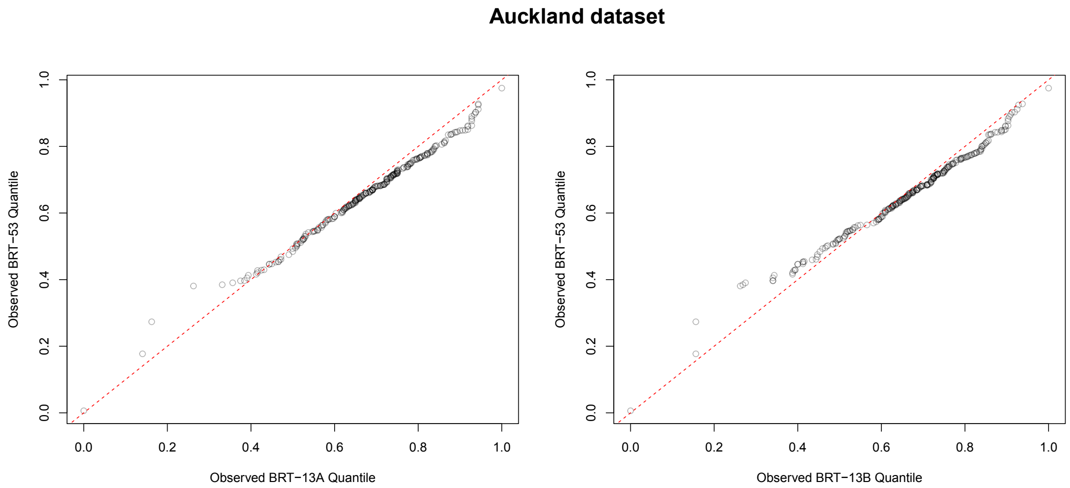

FIGURE B.1: Quantile-Quantile plots of overall resilience scores generated from the Auckland dataset comparing the BRT-13a and BRT13b scales to the BRT-53 scale. The Q-Q plot on the left shows the quantile scores from the BRT-53 compared to the quantile scores of the BRT-13a. The Q-Q plot on the right shows the BRT-53 quantile scores to the BRT-13b quantile scores. For both plots, the dotted red reference line shows a perfect distribution match. Points above the line signify left skew approximations for the corresponding short-form and points below the line signify right skew. The Auckland dataset was the original dataset from which the BRT-53 was defined and developed.

The short-form methodologies appear to closely approximate the full questionnaire for all three datasets. In every case for both short-form versions, the distributions of organisational results were very similar in both shape and location. To determine the most accurate approximations, the results from the two short-form versions were assessed based on their correlation to the BRT-53.

Correlations between the BRT-53 and the short-forms (BRT-13a and BRT-13b) were assessed at the overall resilience score and the factor (adaptive capacity and planning) levels. As shown in Table B.3, the BRT-53 and BRT-13a strongly correlate and are

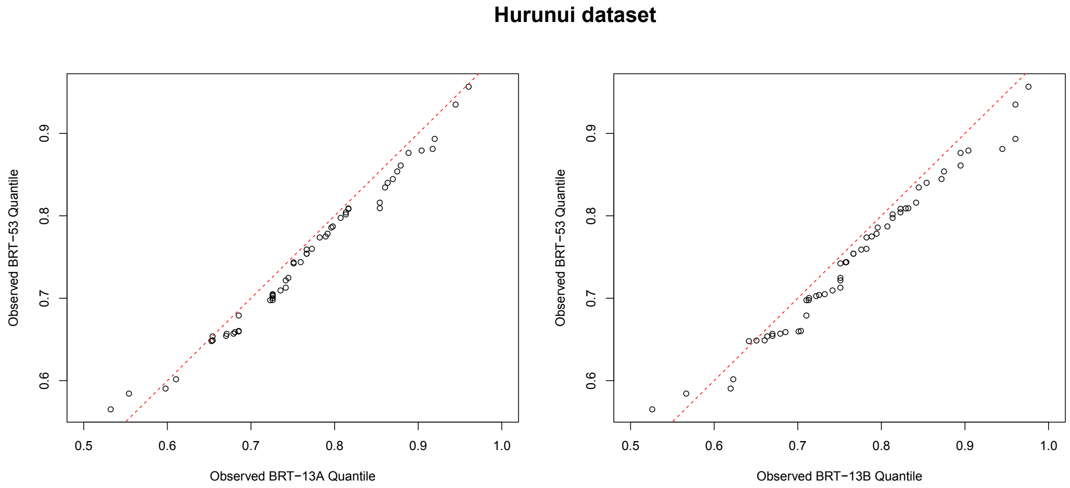

FIGURE B.2: Quantile-Quantile plots of overall resilience scores generated from the Hurunui dataset comparing the BRT-13a and BRT13b scales to the BRT-53 scale. The Q-Q plot on the left shows the quantile scores from the BRT-53 compared to the quantile scores of the BRT-13a. The Q-Q plot on the right shows the BRT-53 quantile scores to the BRT-13b quantile scores. For both plots, the dotted red reference line shows a perfect distribution match. Points above the line signify left skew approximations for the corresponding short-form and points below the line signify right skew. The Hurunui dataset was the second dataset used to test the BRT-53 on rural organisations.

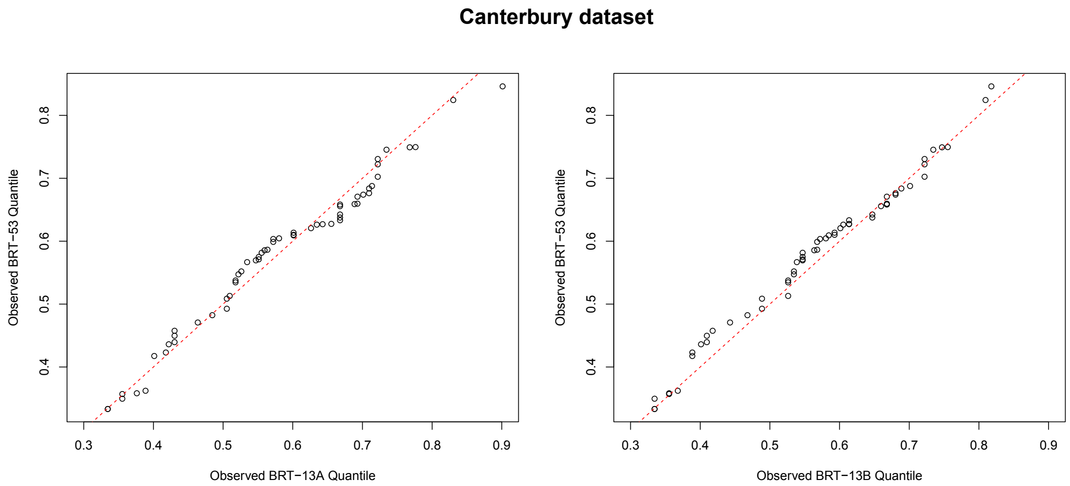

FIGURE B.3: Quantile-Quantile plots of overall resilience scores generated from the Canterbury dataset comparing the BRT-13a and BRT13b scales to the BRT-53 scale. The Q-Q plot on the left shows the quantile scores from the BRT-53 compared to the quantile scores of the BRT-13a. The Q-Q plot on the right shows the BRT-53 quantile scores to the BRT-13b quantile scores. For both plots, the dotted red reference line shows a perfect distribution match. Points above the line signify left skew approximations for the corresponding short-form and points below the line signify right skew. The Canterbury dataset was the third dataset used to test the BRT-53 on organisations, date were collected following the 4 September 20102 Darfield earthquake.

significant for all datasets for the overall resilience score. The internal structure of the BRT-13a index was consistent with the results of the BRT-53 as the BRT-13a adaptive capacity and planning factors correlated significantly to the BRT-53 factor results in all three datasets. The BRT-13b was also highly correlated to the BRT-53 overall resilience score, again with all r values exceeding 0.9 and significant. Compared to the performance of the BRT-13a, the BRT-13b overall resilience score showed stronger correlations to the BRT-53 for 2 of the 3 datasets. However, in terms of factor correlations to the BRT-53, the results were mixed and determining the better correlating short-form for factor resolution is difficult.

Table B.3: BRT-53 to BRT-13a and BRT13b factor and model correlations for all datasets using Spearman Rank Order Correlations with significance levels of $p<0.0005$.

	Auckland		Hurunui		Canterbury	
	BRT-53-BRT-13A	BRT-53-BRT-13B	BRT-53-BRT-13A	BRT-53-BRT-13B	BRT-53-BRT-13A	BRT-53-BRT-13B
Planning Factor	0.9194	0.9323	0.9024	0.8868	0.9389	0.9361
Adaptive Capacity Factor	0.9181	0.8358	0.9377	0.9606	0.8486	0.9293
Overall Resilience	0.9401	0.9892	0.9536	0.9418	0.9582	0.9684

The verification of the internal reliability of the summary score was assessed to assist in judging the more appropriate short-form version. The reliabilities of the overall resilience score and its constituent factors for the BRT-53, the BRT-13a and the BRT-13b were assessed using Cronbach's Alpha. The BRT-53 gained values of 0.95 for all datasets, which reflects very high internal reliability. Again for all three datasets, the internal reliabilities for the two factors within the BRT-53, planning and adaptive capacity, gained values of at least 0.88 and 0.89 respectively. Consistent with test construction theory [393, 394], the shortened scales (the BRT-13a and the BRT-13b) recorded lower reliability coefficients than the longer scale (BRT-53) from which it was derived. Even so, the BRT-13a recorded alpha coefficients between 0.84 and 0.87 and the BRT-13b between 0.85 and 0.88, which is highly reliable for a 13-item scale [393, 394]. The Cronbach's alpha values generated for the two factors within the BRT-13a and the BRT-13b were also lower than what was observed in the BRT-53. The planning factor scored between 0.65 and 0.74 for the BRT-13a and 0.67 and 0.75 for the BRT-13b, which is low relative to the BRT-53 values, but reliable for a 5-item scale [388]. For both short-form versions, the adaptive capacity factor results were highly reliable for an 8-item scale. The BRT-13b showed consistently higher, but relatively minor improvements in reliability coefficients to the BRT-13a. All results from the reliability tests can be found in Table B.4.

Table B.4: Cronbach's alpha values of both short-forms derived from the different datasets.

		Cronbach's alpha		
Factor	Scale	Auckland	Hurunui	Canterbury
Planning	BRT-13A	0.73	0.65	0.74
	BRT-13B	0.75	0.67	0.74
	BRT-53	0.89	0.88	0.94
Adaptive Capacity	BRT-13A	0.79	0.79	0.83
	BRT-13B	0.82	0.87	0.86
	BRT-53	0.94	0.95	0.96
Total Resilience	BRT-13A	0.84	0.85	0.87
	BRT-13B	0.85	0.86	0.88
	BRT-53	0.95	0.95	0.97

B.8 Discussion

From previous deployments of the BRT-53 survey, it was found that when the BRT-53 was used as a module measuring organisational resilience within larger questionnaires assessing the impacts and effects of disaster, the long survey led to low response rates and high item omission frequencies. High omission rates presented a number of challenges in terms of missing value analysis and significantly limited the interoperability of data. Due to these challenges, a short-form version offered numerous practical advantages.

In limiting a 53-item questionnaire to a short-form 5-minute survey, single items were used to represent the theoretical constructs, a technique that has been employed with success in several other cases [384, 389, 395–399]. To decrease survey length and fatigue, short-form versions often sacrifice two things: comprehensiveness and precision of measurement. In this study, it was decided that the analysis of two methodologies that placed more importance on either theoretical comprehensiveness or measurement precision was necessary to determine which version was most successful. The BRT-13a was developed with a methodology that focused on the comprehensiveness of the theoretical constructs through the selection of the most theoretically representative items per indicator. The BRT-13b was developed to attain the most precise total overall resilience score possible by using the strongest correlating items possible. Both short-form versions were designed to produce factor scores and overall resilience scores that could be compared to the results of the BRT-53.

In testing the more appropriate version, three populations from different locations, disaster contexts, and comprised of different types of organisational sectors and sizes were sampled in New Zealand. For all three datasets, both short-forms showed highly similar distribution shapes and localities to that of the BRT-53. Both short-forms produced reliable results and correlated strongly to the BRT-53 overall resilience scores as well as for the two factor scores (adaptive capacity and planning). While both short-forms performed very similarly across all three datasets, the BRT-13b showed stronger reliabilities to the BRT-13a and therefore is slightly more precise in representing the BRT-53. Furthermore, the overall resilience scores for the BRT-13b were more highly correlated to the BRT-53. Therefore, the BRT-13b proved to be the more successful short-form version of the BRT-53. The complete list of items contained in the BRT-13b are shown in Table B.5.

B.8.1 Limitations

The original BRT-53 model was developed through results derived from organisations within three contextually distinct areas of New Zealand. One dataset was derived from an area that had no recent experience with natural hazards and was heavily urbanized while the other two datasets were derived from both rural and urban areas with recent natural hazard experiences. Therefore, while the results of the BRT-13a and BRT-13b showed close associations with the results of the BRT-53, comparisons between different sample sets is at this stage unconstrained and analysing the differences between sample groups is not advised. Furthermore, because all sample sets were derived from organisations within New Zealand, the BRT-53 and both BRT-13 versions should be tested in other countries to better understand potential differences in the interpretation

Table B.5: BRT-13b item list with corresponding indicator code

Factor	Indicator	Item
Planning	P1	We are mindful of how a crisis could affect us
	P2	We believe emergency plans must be practised and tested to be effective
	P3	We are able to shift rapidly from business-as-usual to respond to crises
	P4	We build relationships with organisations we might have to work with in a crisis
	P5	Our priorities for recovery would provide direction for staff in a crisis
Adaptive Capacity	AC1	There is a sense of teamwork and camaraderie in our organisation
	AC2	Our organisation maintains sufficient resources to absorb some unexpected change
	AC3	People in our organisation 'own' a problem until it is resolved
	AC4	Staff have the information and knowledge they need to respond to unexpected problems
	AC5	Managers in our organisation lead by example
	AC6	Staff are rewarded for 'thinking outside the box'
	AC7	Our organisation can make tough decisions quickly
	AC8	Managers actively listen for problems

of single items. Further deployment of the BRT-53 or BRT-13 short-forms would help constrain these contextually driven variables.

B.9 Conclusions

It should be noted, from the results discussed above, that both BRT-13a and BRT-13b can be used in place of the BRT-53. However, BRT-13b shows slightly higher values for Cronbach's Alpha than BRT-13a and is therefore the most appropriate short-form version of the BRT-53. The preliminary results presented in this appendix chapter show that using the BRT-13b would be an accurate representation of the BRT-53. The short-form version significantly decreases survey fatigue by reducing the total items considerably while still providing reliable and valid single value indices for organisational resilience as well as for the latent factors: planning and adaptive capacity. Further research is required to determine the BRT-13b's response and item omission rate as well as the test/re-test reliability.

The quantification of organisational resilience is a highly sought-after metric. For practitioners, identifying organisational characteristics that relate to resilience provides the starting point for increasing resilience. However, the current methodology for quantifying organisational resilience is time and energy expensive for the individual and a more concise method increases the application of the tool and may provide for more frequent assessments over time. By creating a short-form version of the BRT-53 tool, the usability for the end-user is increased, along with the likelihood of first-time users to participate. Researchers interested in the results should see increased response rates during surveys as well as decreased omission rates and survey fatigue. In addition, for organisations interested in quantifying their resilience, the short-form version facilitates a more rapid and less costly assessment process. The short-form version would also readily support repeated measurement of resilience over time to determine the effectiveness of any resilience development programme.

Appendix C

Digital Appendix

The digital appendix includes supplemental research materials developed and used for the data collection process for this thesis. It contains the following files:

C.1 The Hurunui questionnaire

The Hurunui questionnaire was discussed in Chapter 2. The file is titled "Hurunui Questionnaire".

C.2 The Hurunui cover letter

The Hurunui cover letter is the accompanying cover letter, discussed in Chapter 2 that was included with the Hurunui questionnaire. The file is titled "Hurunui Cover Letter".

C.3 The Hurunui reminder notice

The Hurunui reminder notice is the reminder notice that was sent to the non-responsive sample after the first mailing, as discussed in Chapter 2. The file is titled "Hurunui Reminder Notice".

C.4 The Canterbury questionnaire

The Canterbury questionnaire is the questionnaire discussed in Chapters 2, 3 and 4, which was deployed to rural organisations in the Canterbury region following the Darfield earthquake. The file is title “eq1 questionnaire”.

C.5 The Canterbury cover letter

The Canterbury cover letter is the accompanying cover letter included with the Canterbury questionnaire. The file name is “eq1 cover letter”.

C.6 The Farm-specific questionnaire

The Farm-specific questionnaire is the questionnaire discussed in Chapters 2, and 3, which was deployed online only to farming organisations in the Canterbury region following the Darfield earthquake. The file is title “Farm specific questionnaire”.

C.7 The Southland questionnaire

The Southland questionnaire is the questionnaire discussed in Chapters 2, and 6, which was deployed to rural organisations in the Southland region following the 2010 Southland snowstorm. The file is title “snow questionnaire”.

C.8 The Southland cover letter

The Southland cover letter is the accompanying cover letter included with the Southland questionnaire. The file name is “snow cover letter”.

C.9 The "Follow-up" questionnaire

The "Follow-up" questionnaire is the questionnaire discussed in Chapters 2, 4 and 5, which was deployed to rural organisations in the Canterbury region after approximately 1.5 years following the Darfield earthquake. The file is title "followup questionnaire".

C.10 The "Follow-up" cover letter

The "Follow-up" cover letter is the accompanying cover letter included with the "Follow-up" questionnaire. The file name is "followup cover letter".

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